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Patel et al.

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(54) **ANTENNA SYSTEM WITH MULTIPLE SYNCHRONOUSLY MOVABLE FEEDS**

(71) Applicant: **Sea Tel, Inc.**, Concord, CA (US)

(72) Inventors: **Trushar D. Patel**, Hercules, CA (US); **Tuncer Ede**, Pittsburg, CA (US)

(73) Assignee: **Sea Tel, Inc.**, Concord, CA (US)

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(51) **Int. Cl.**

H01Q 19/10	(2006.01)
H01Q 19/18	(2006.01)
H01Q 5/35	(2015.01)
H01Q 1/12	(2006.01)
H01Q 1/34	(2006.01)

(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 19/18*** (2013.01); ***H01Q 1/1264*** (2013.01); ***H01Q 1/34*** (2013.01); ***H01Q 3/08*** (2013.01); ***H01Q 5/35*** (2015.01); ***H01Q 19/19*** (2013.01); *H01Q 1/42* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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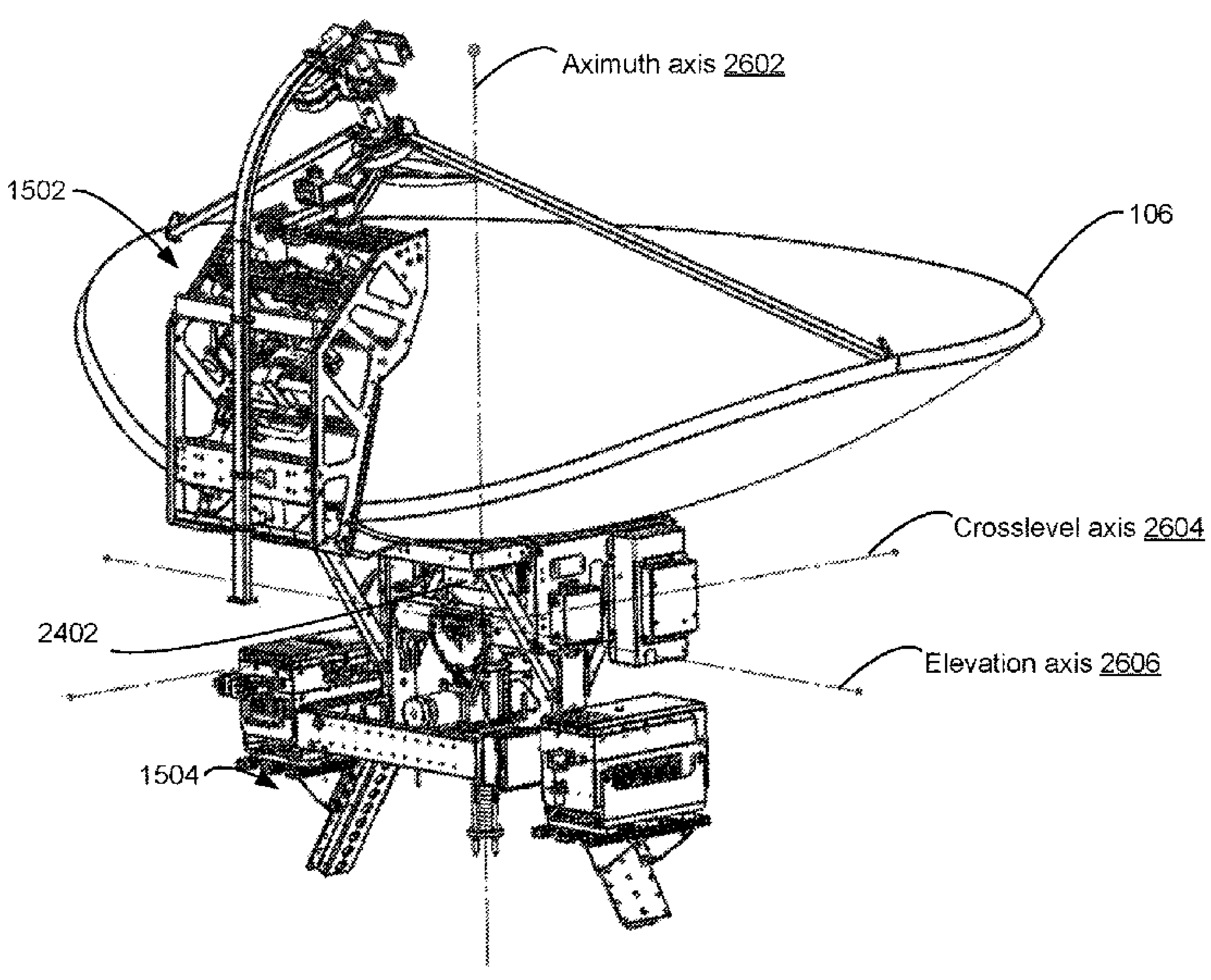
Primary Examiner — Trinh V Dinh
(74) *Attorney, Agent, or Firm* — Morgan, Lewis & Bockius LLP

(57) **ABSTRACT**

The antenna system and the method receive signals having radio frequencies in a plurality of radio frequency bands. The antenna system includes a support assembly, a primary reflector that is coupled to the support assembly, a feed assembly that is movably coupled to the support assembly, and a first feed and a second feed fixedly coupled to the feed assembly. The first feed and the second feed are configured to communicate RF signals in a first frequency band and a second frequency band, respectively, of the plurality of frequency bands. The antenna system also includes a first actuator that is configured to move the feed assembly from a first feed assembly position, where the first feed is positioned along a first signal path with the primary reflector, to a second feed assembly position, where the second feed is positioned along a second signal path with the primary reflector.

24 Claims, 38 Drawing Sheets



(51) **Int. Cl.**

H01Q 3/08	(2006.01)
H01Q 19/19	(2006.01)
H01Q 1/42	(2006.01)

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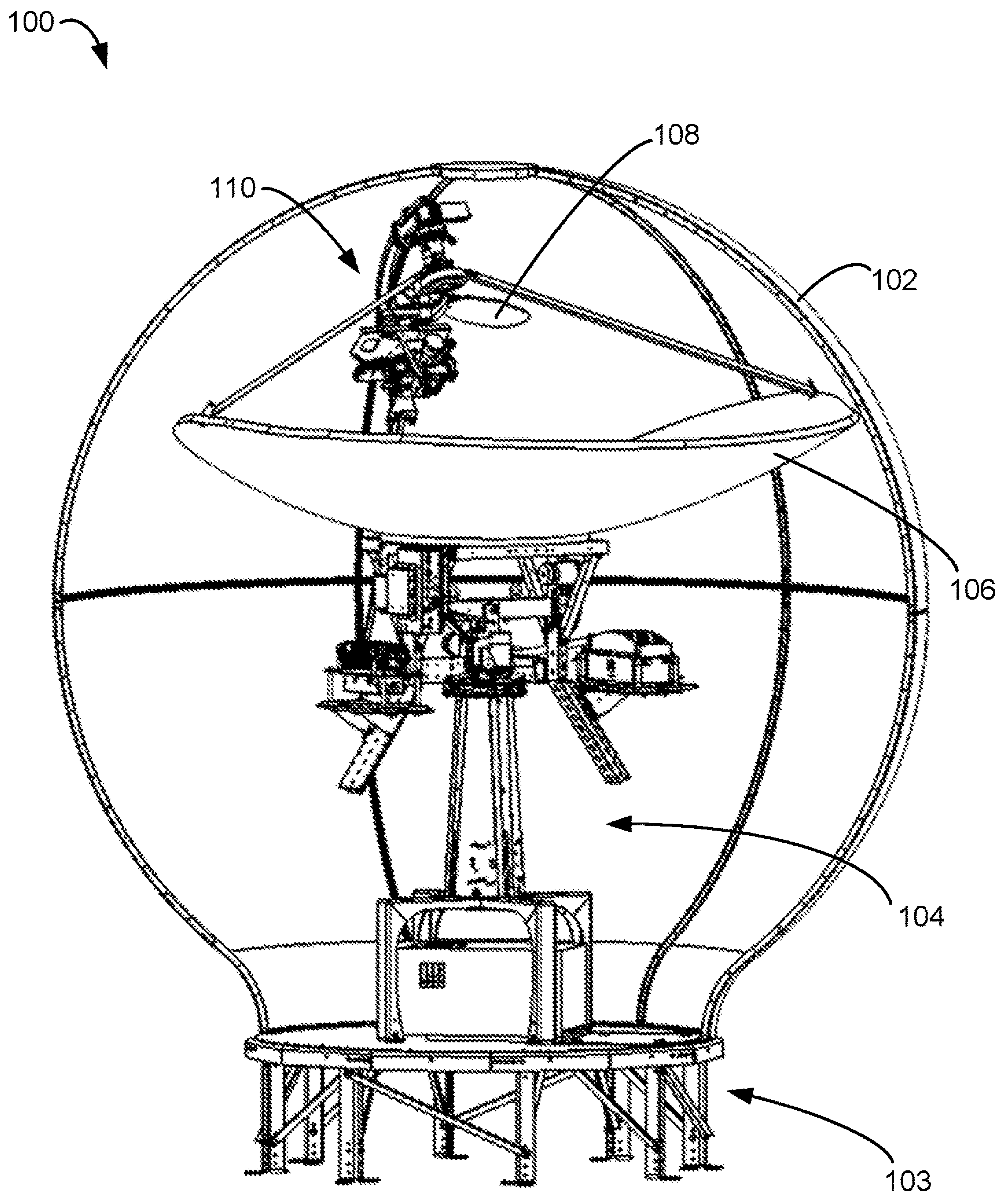

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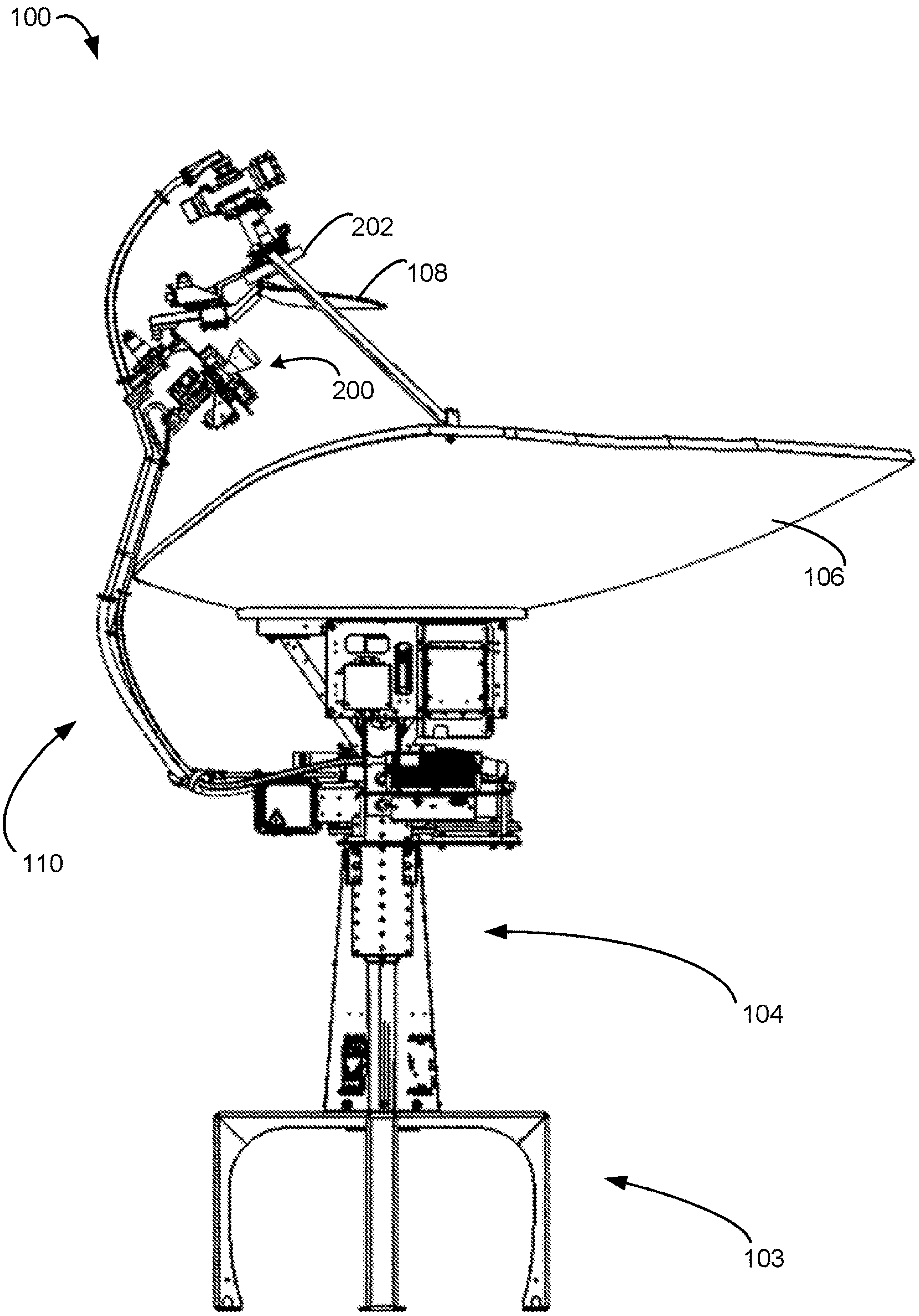

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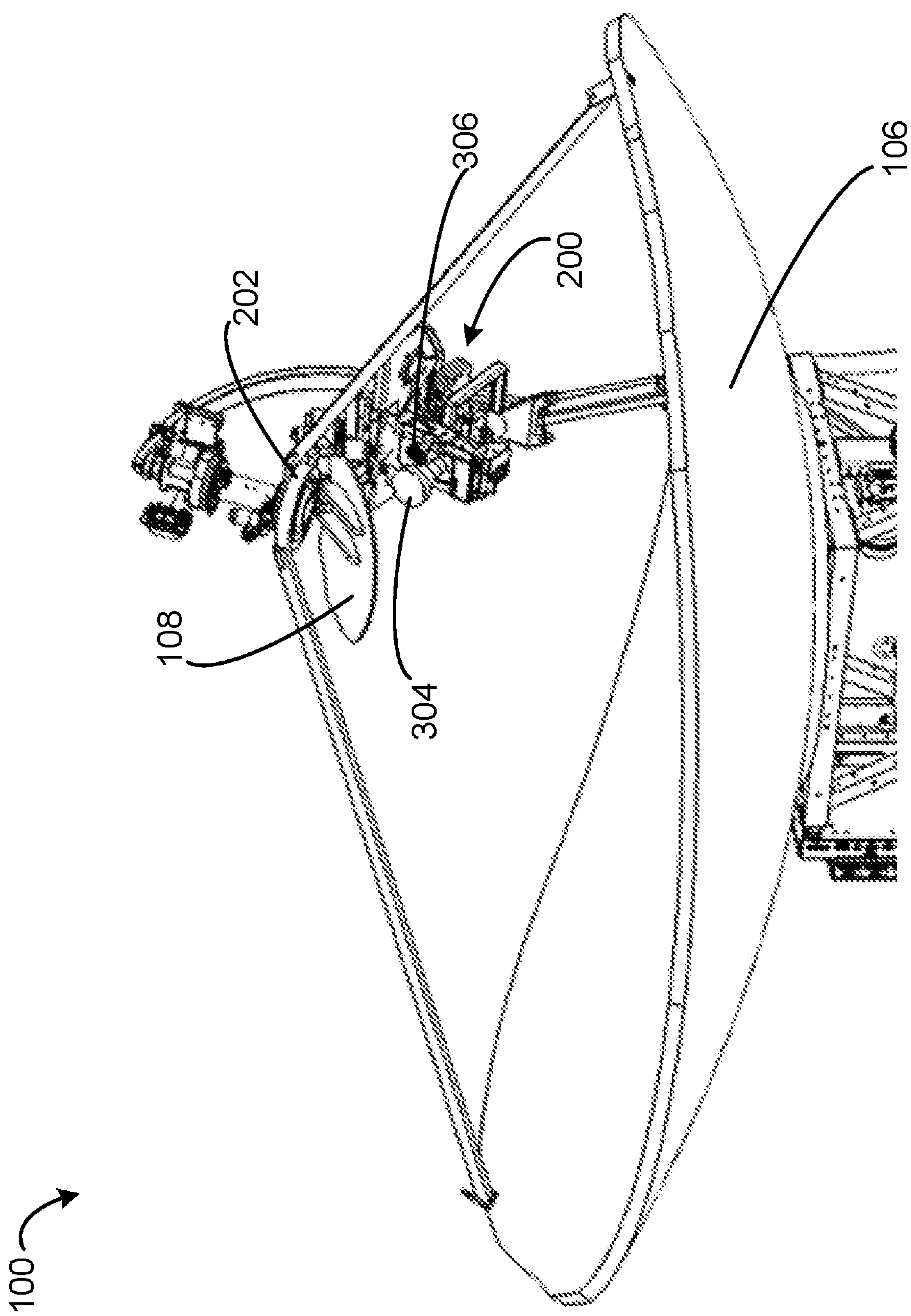

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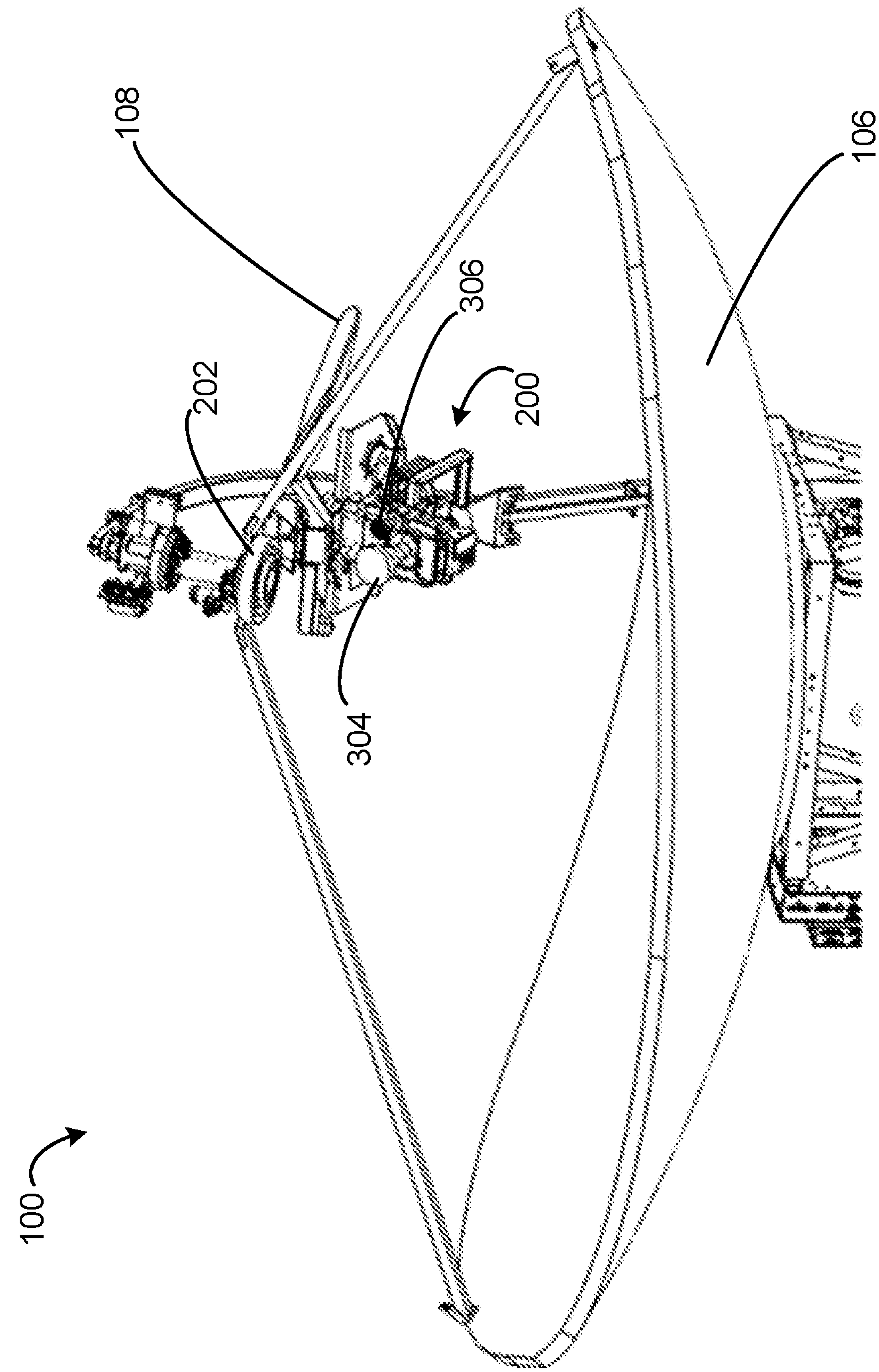

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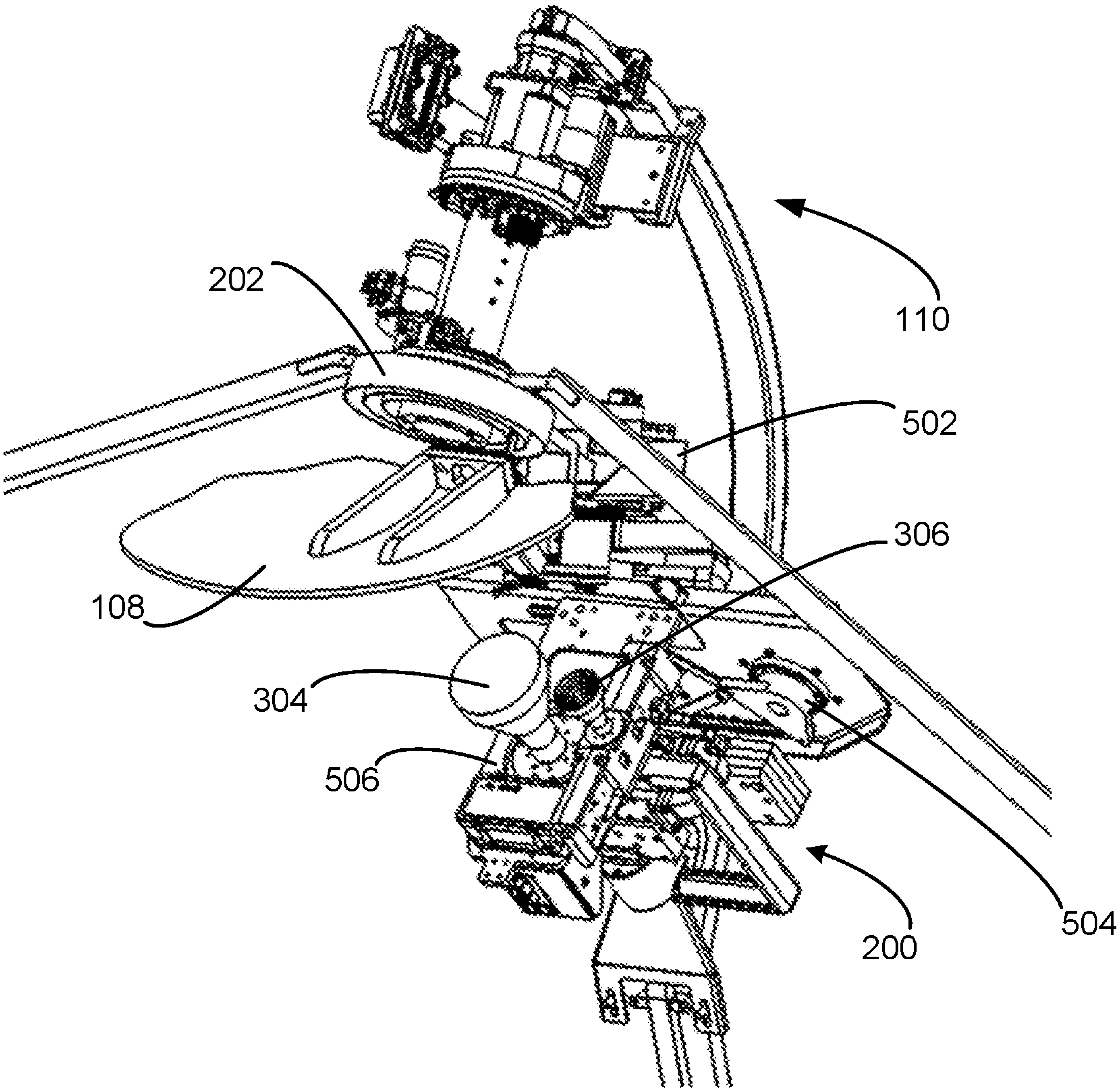

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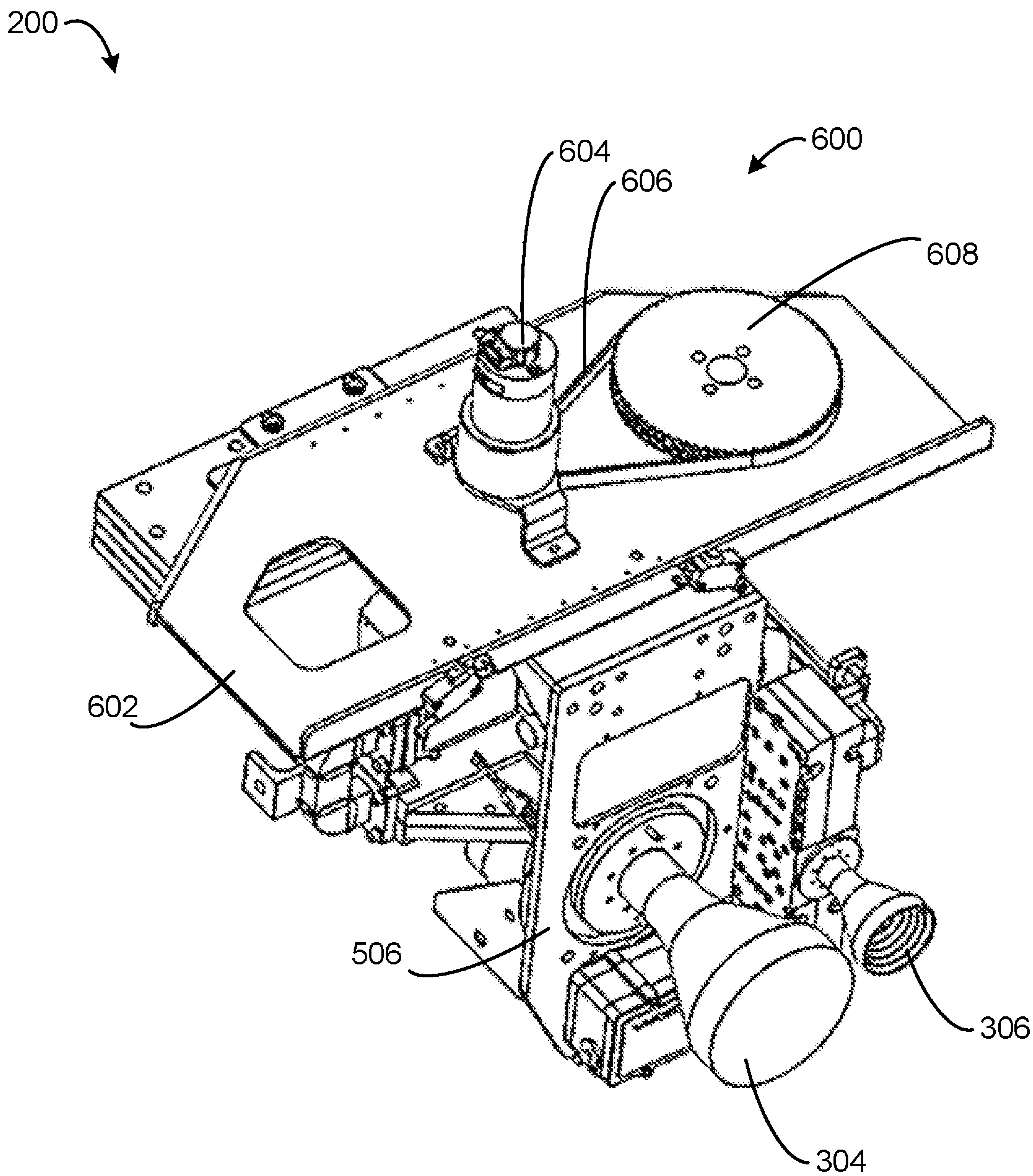

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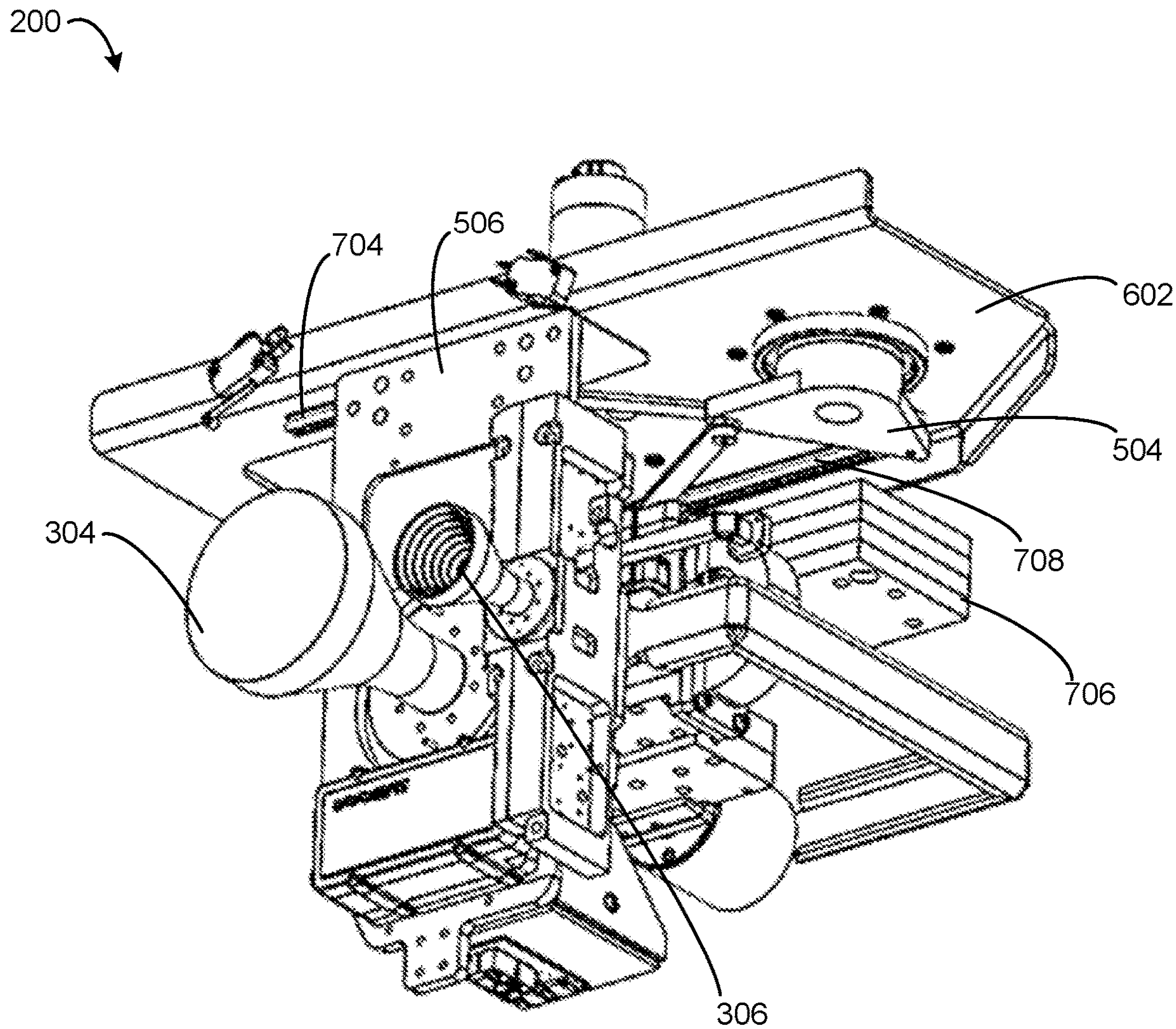

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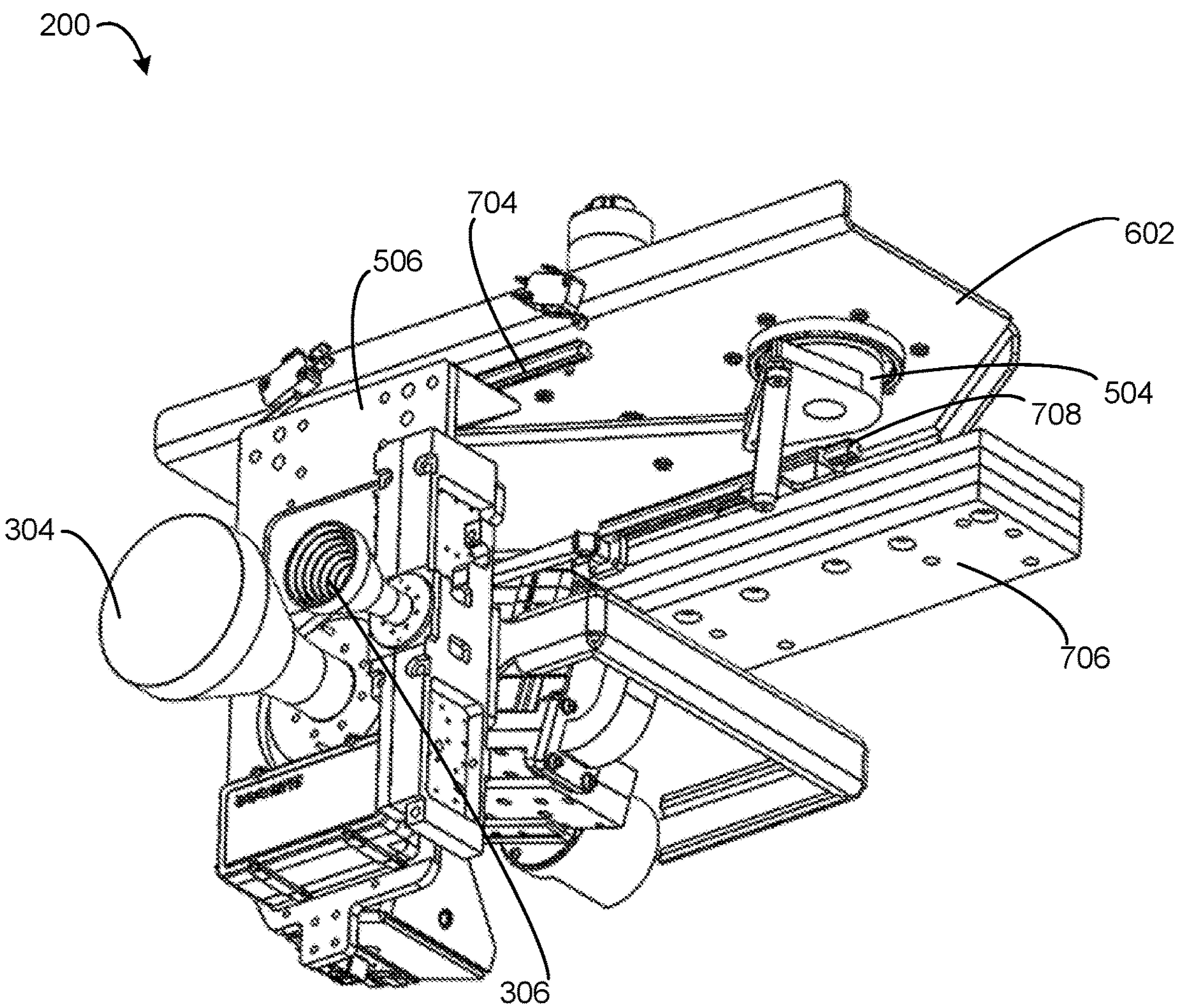

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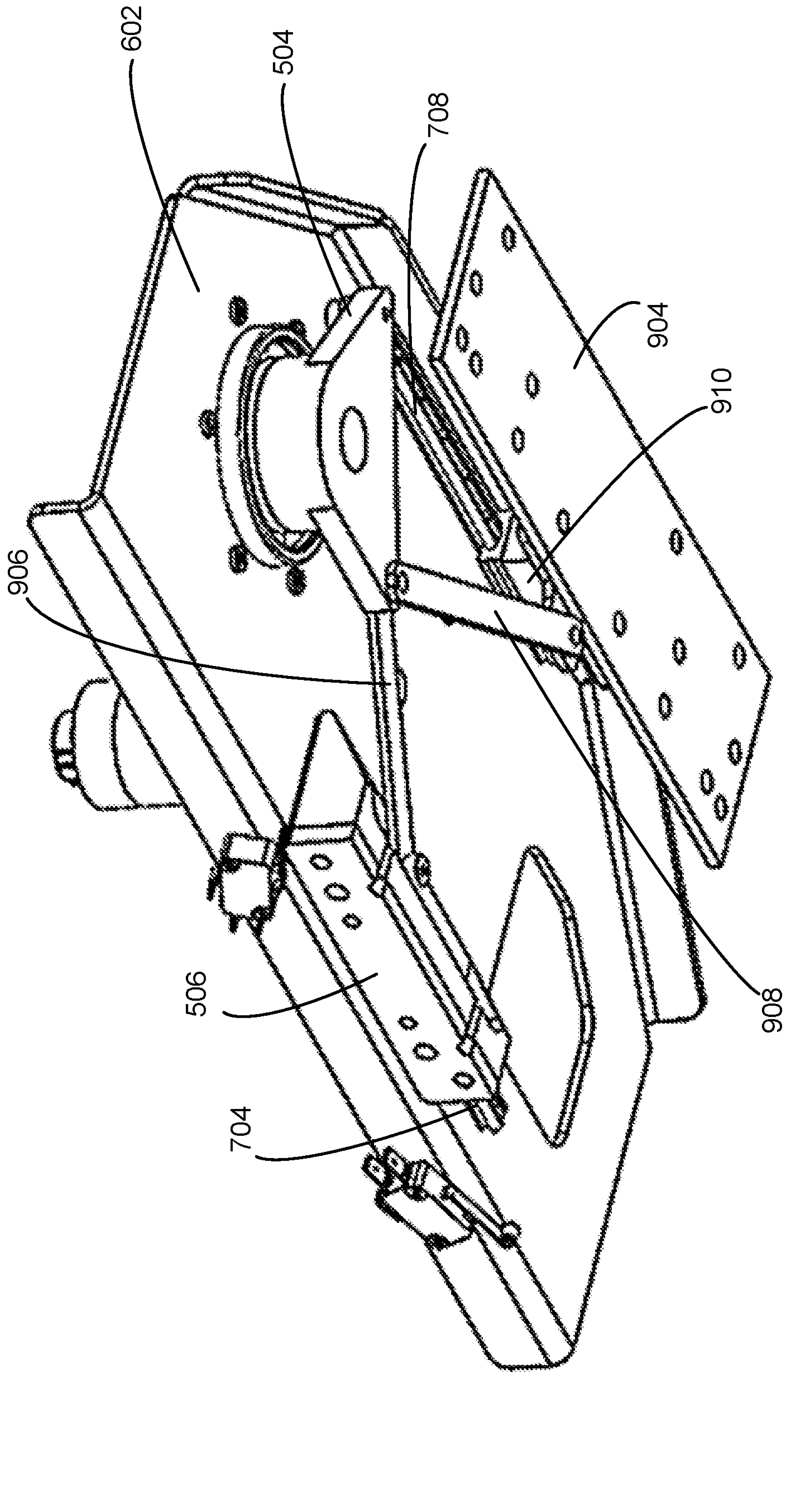

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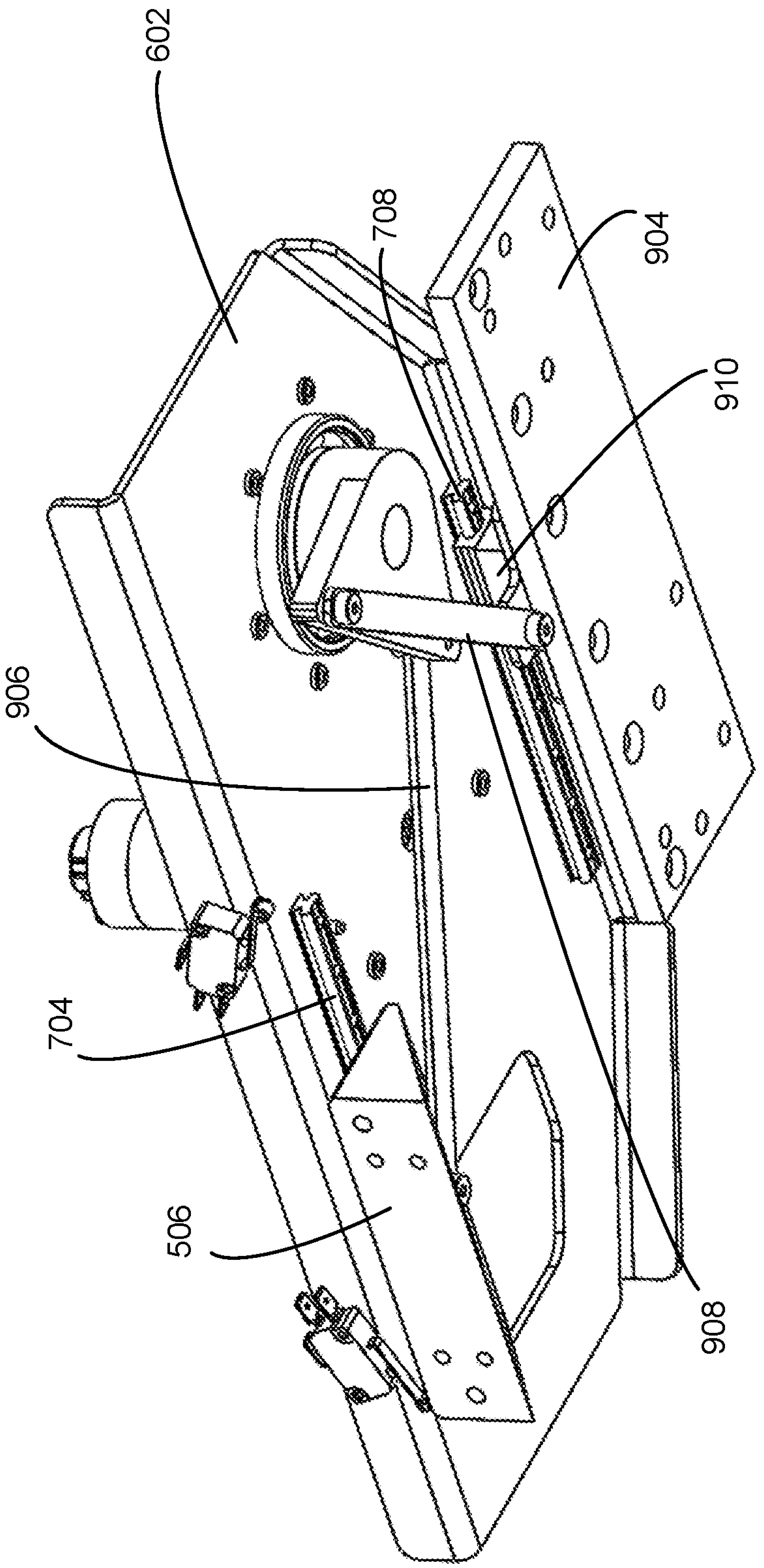

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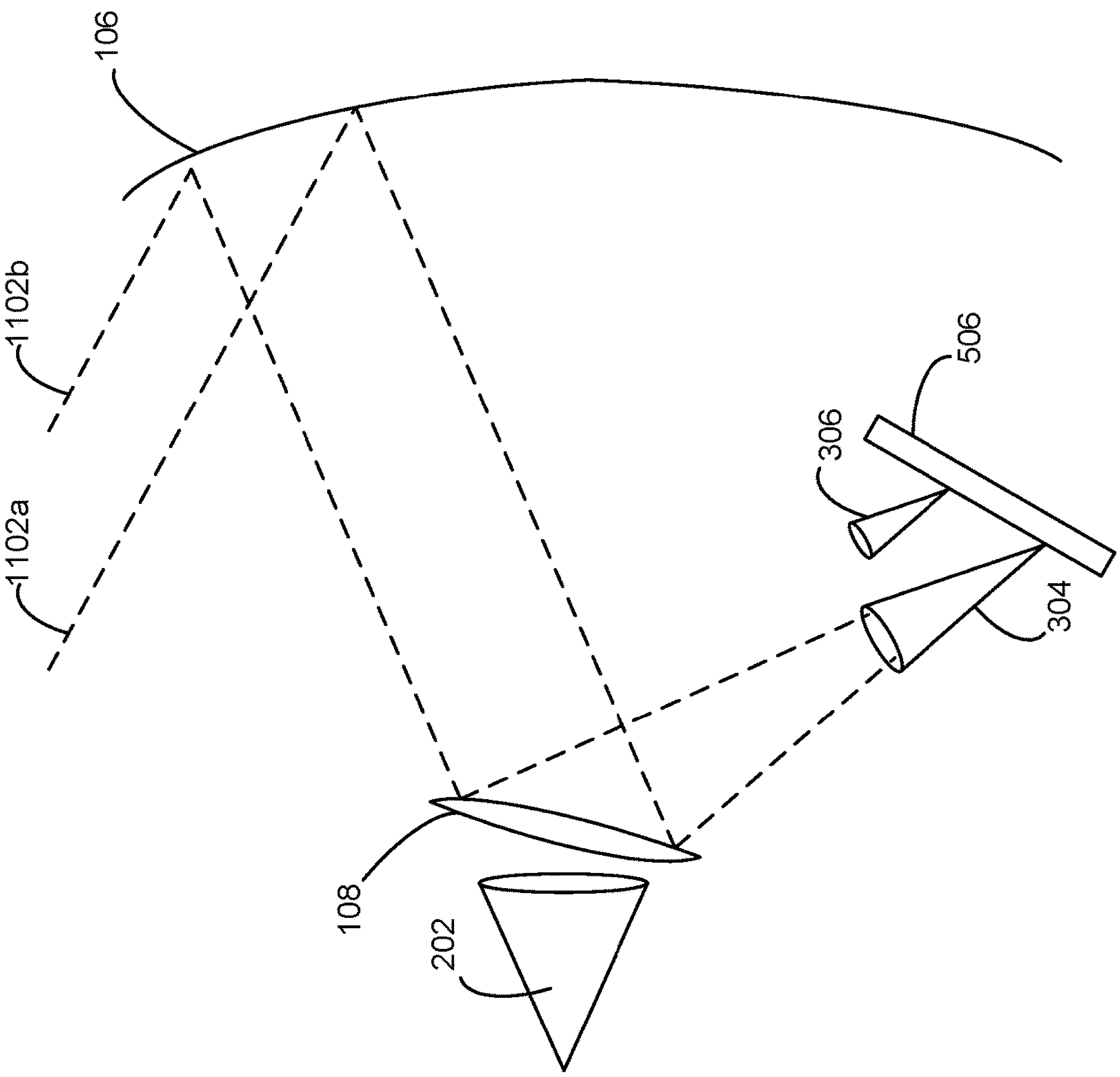

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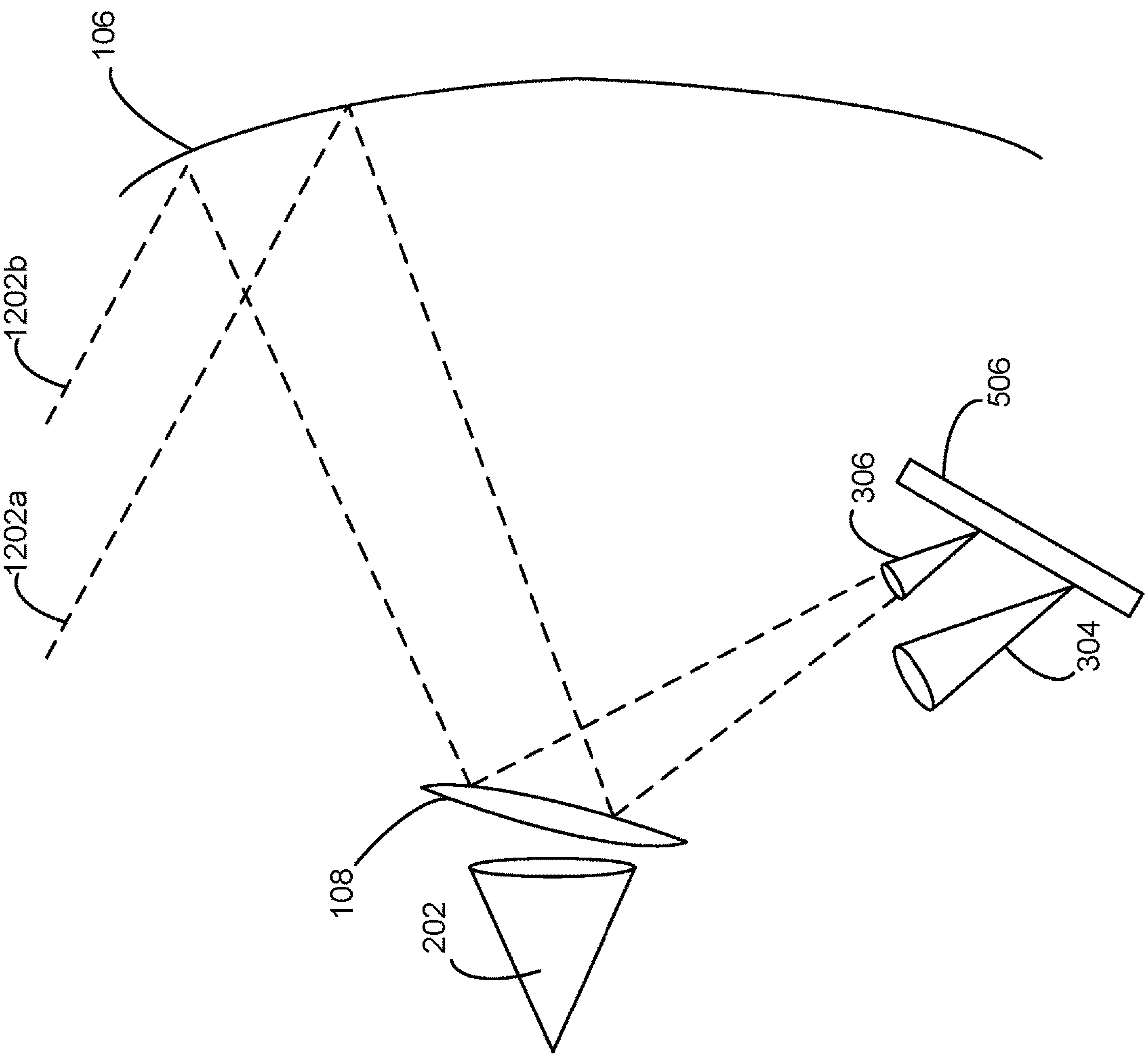

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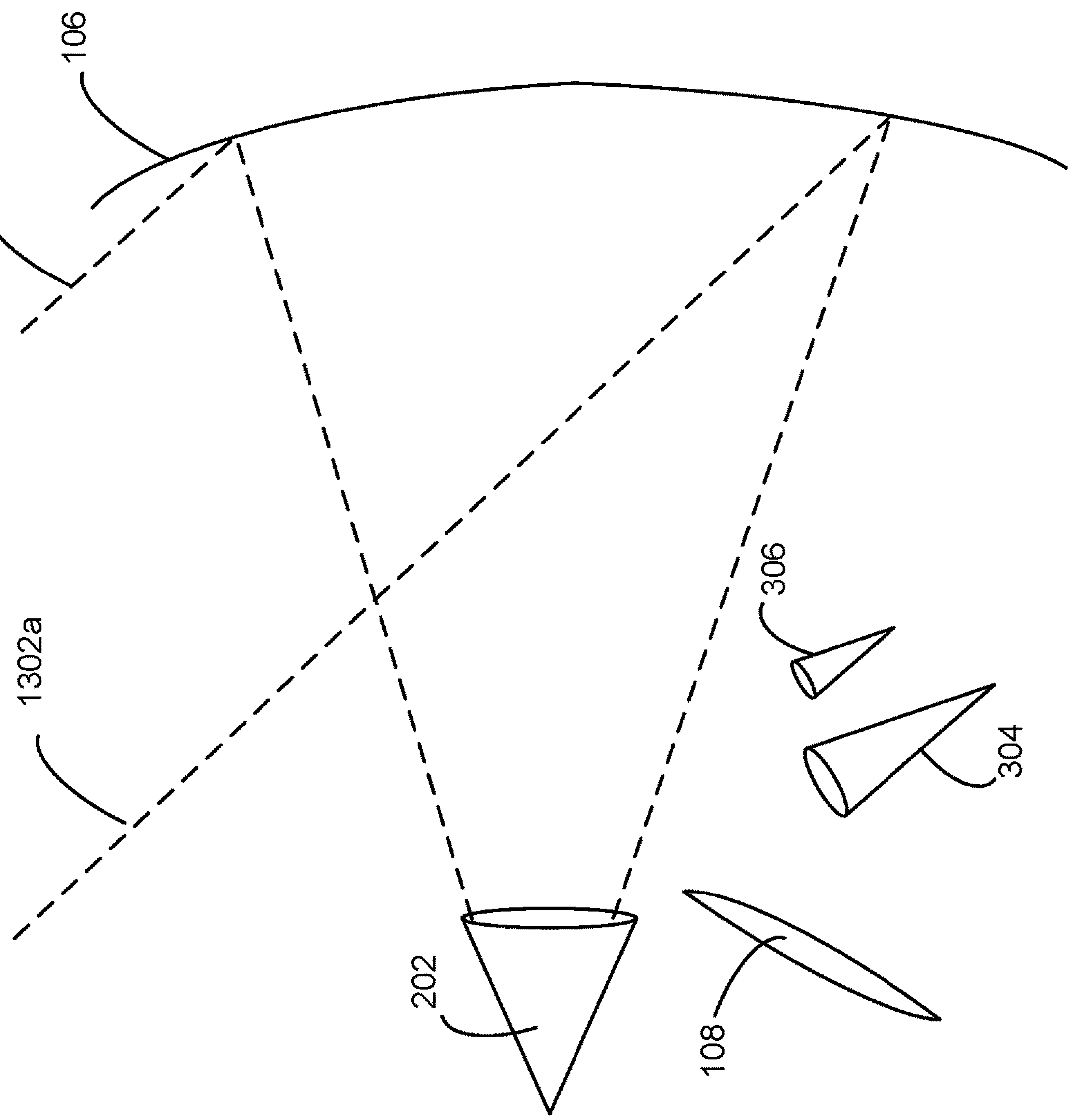

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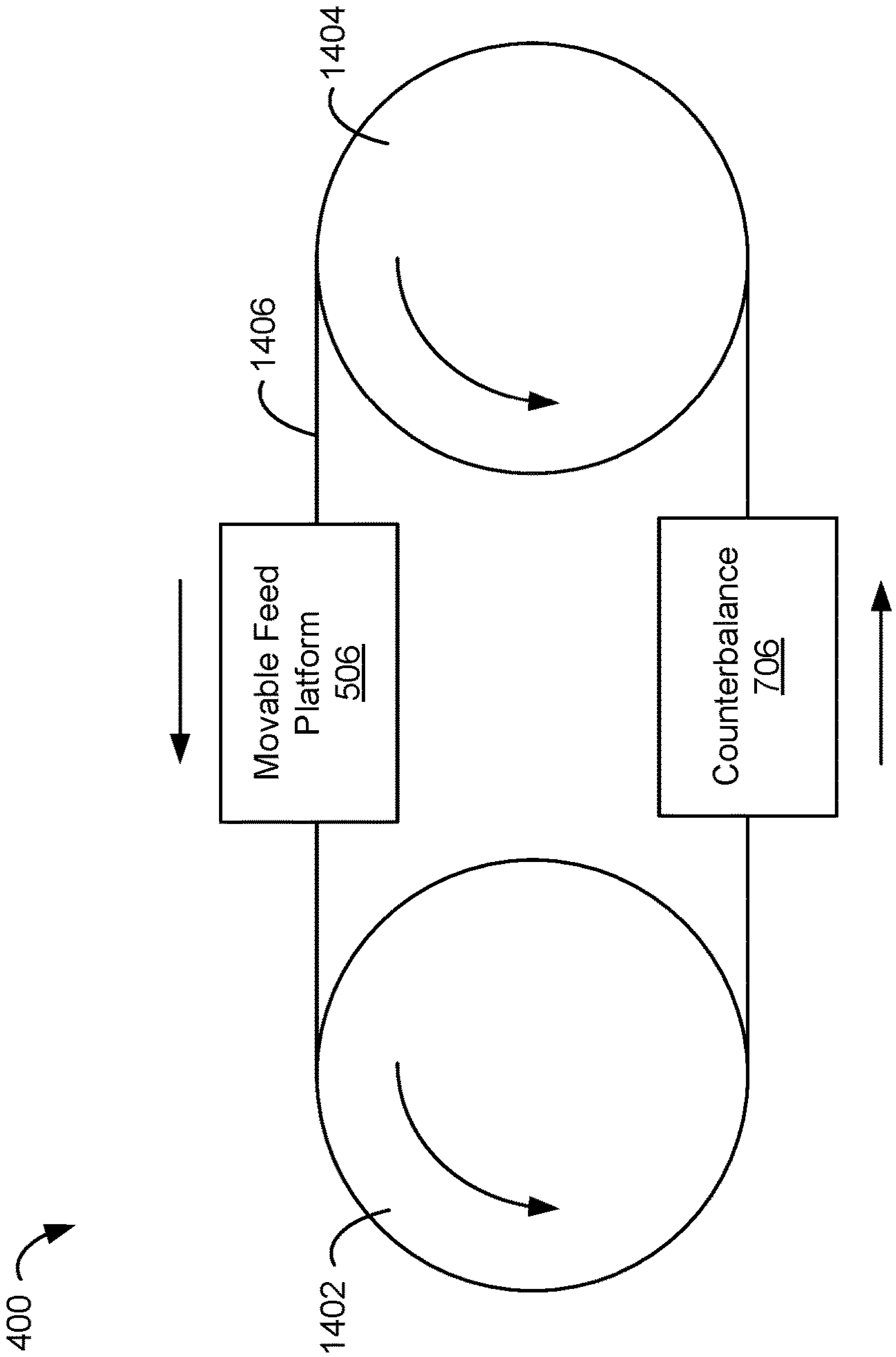
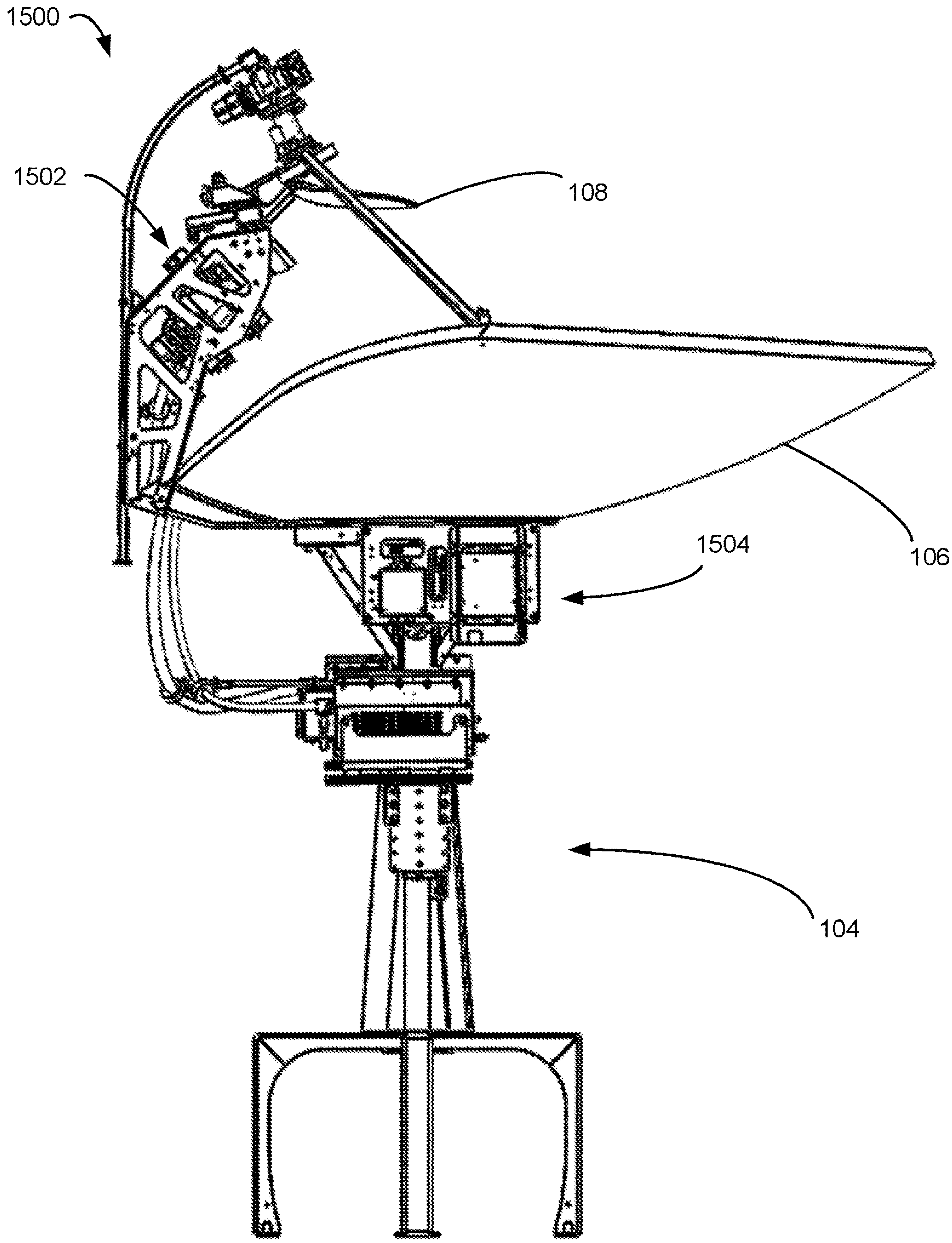

1400
1402
1404
1406
Movable Feed Platform
506
Counterbalance
706

Figure 14



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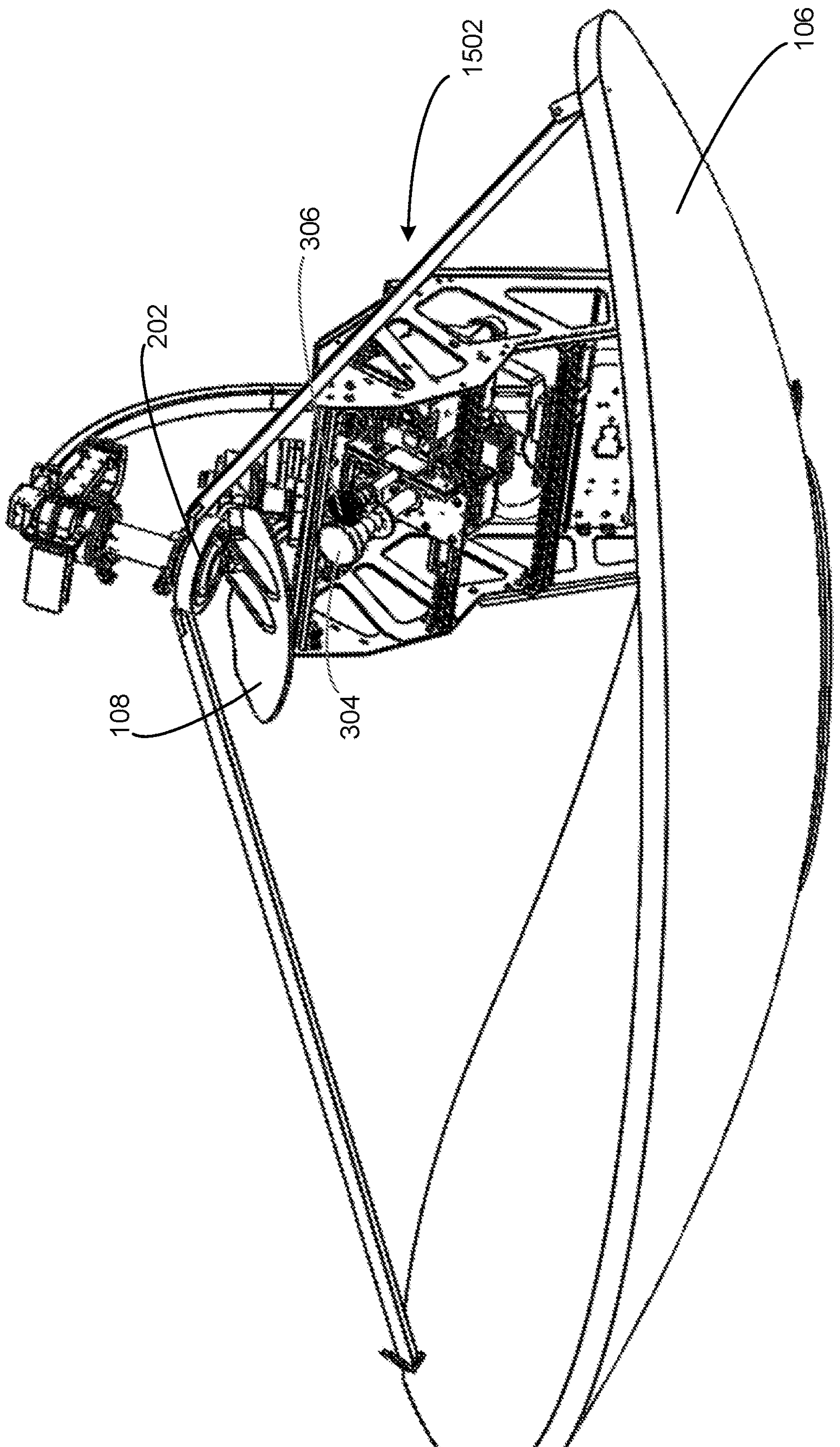

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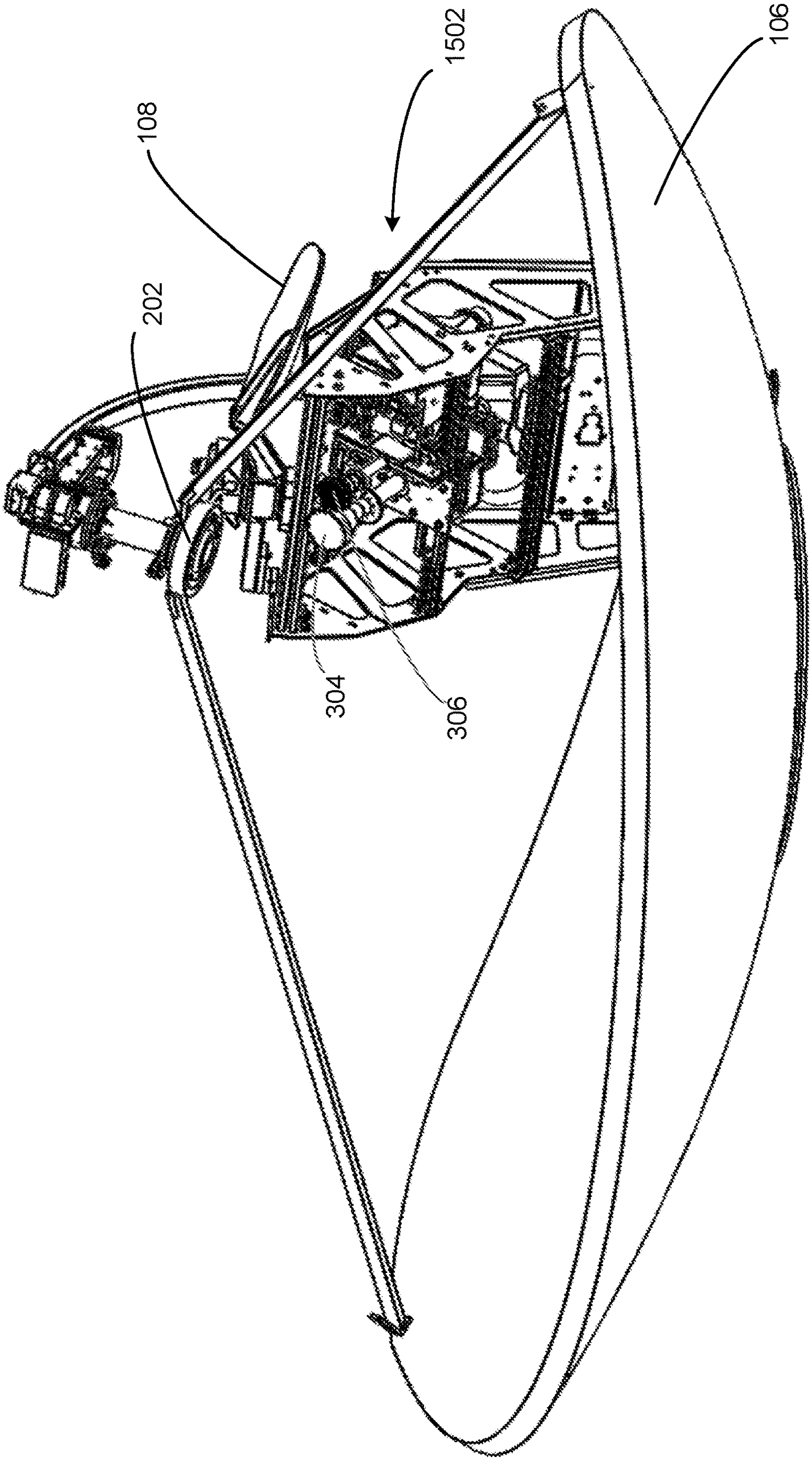

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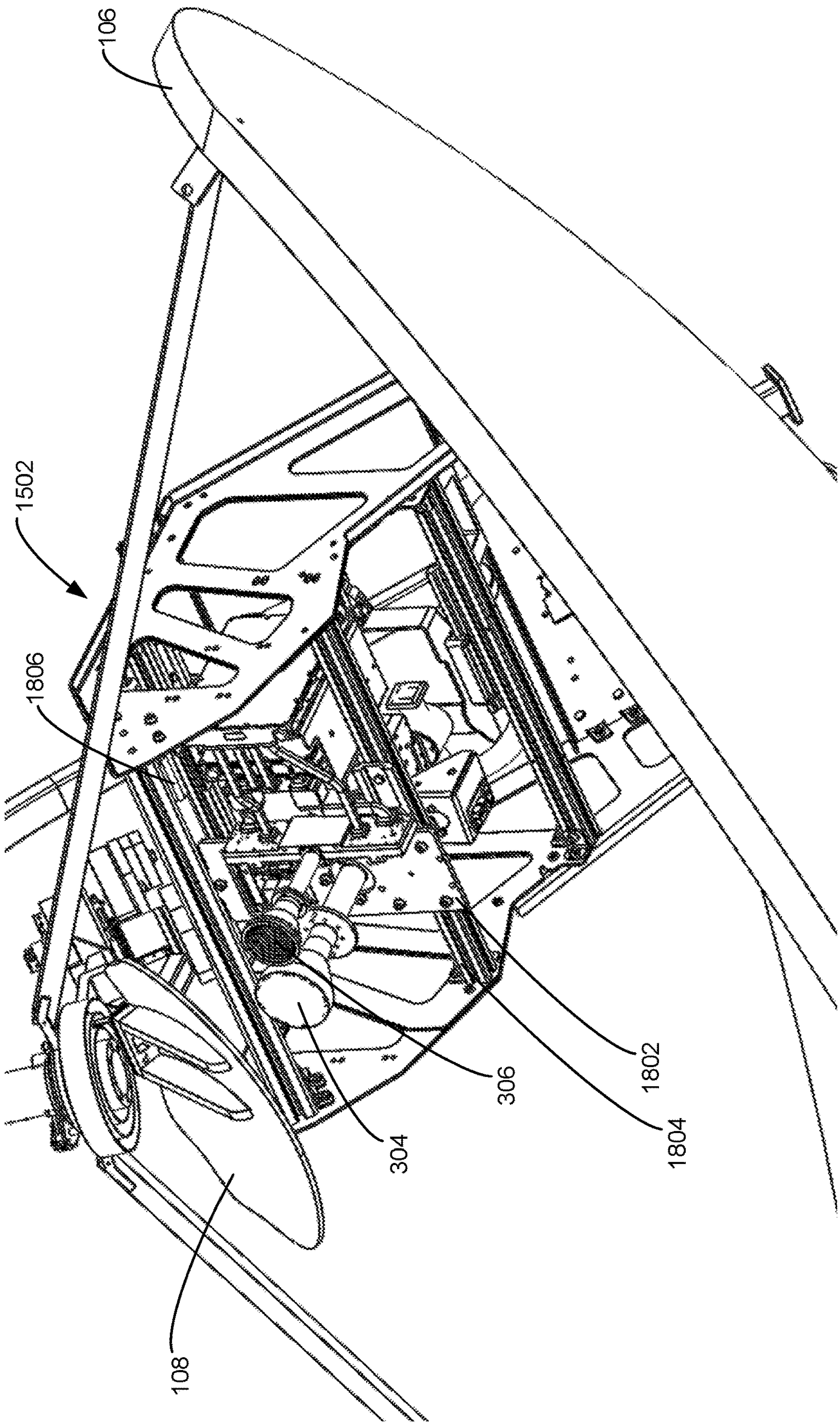

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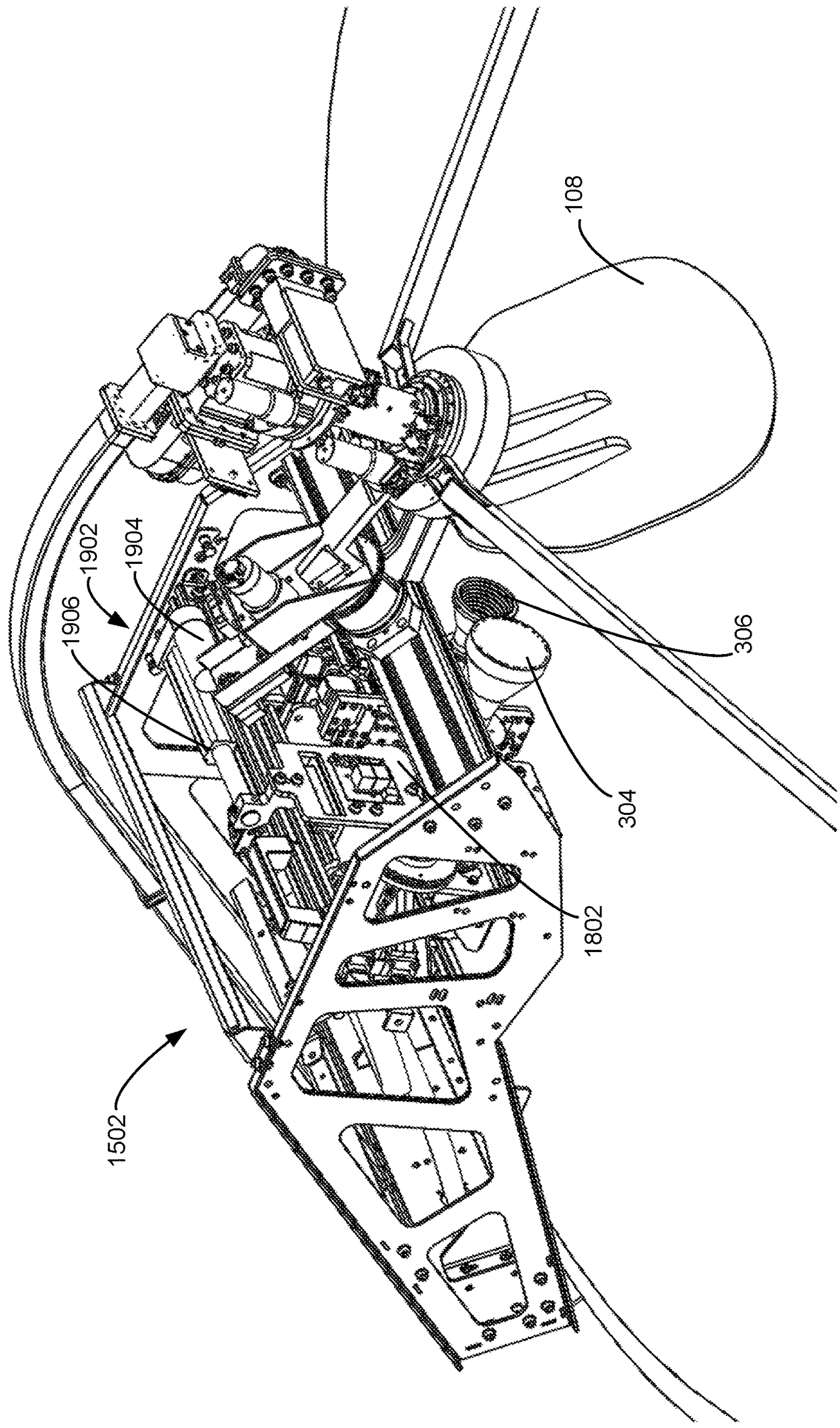

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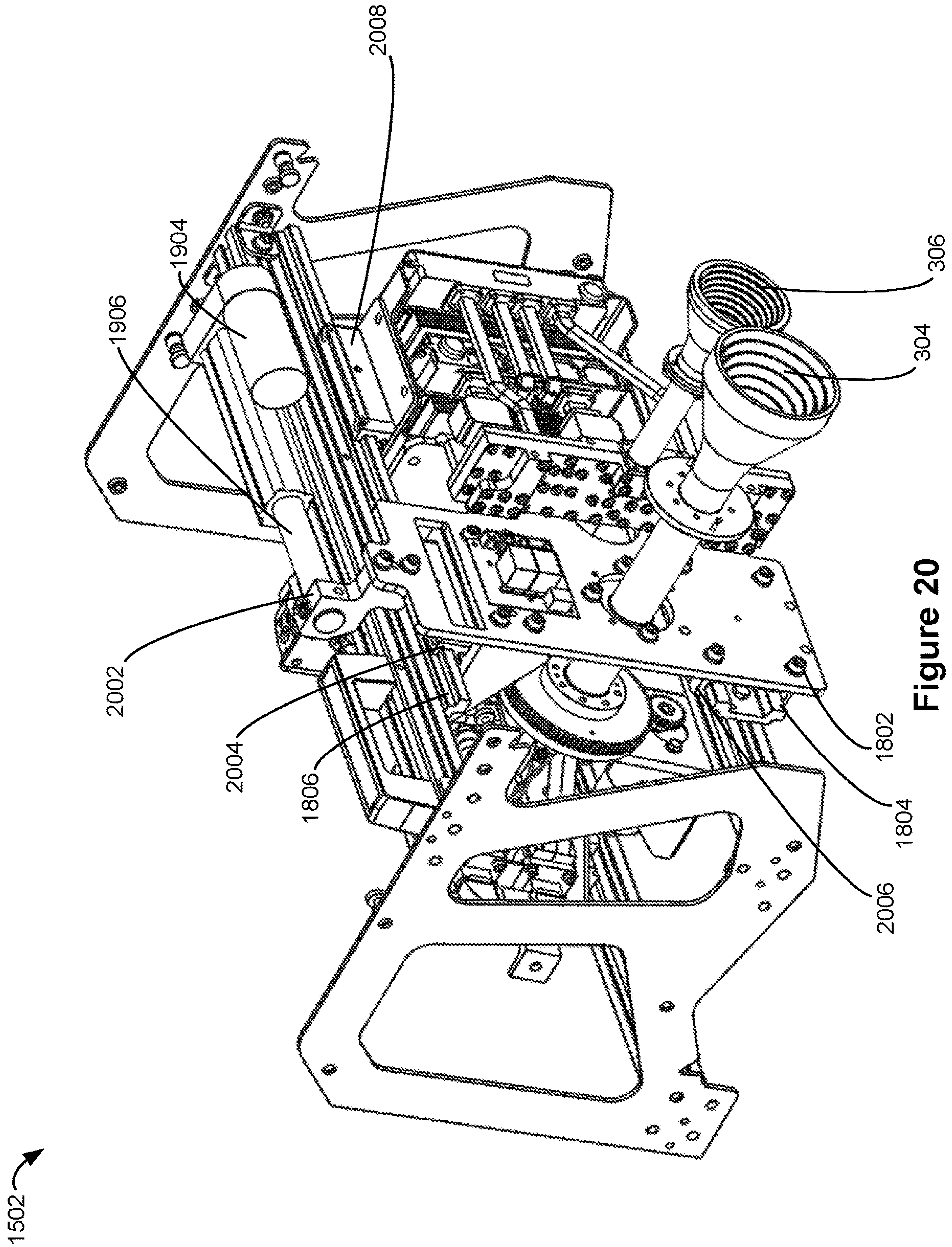

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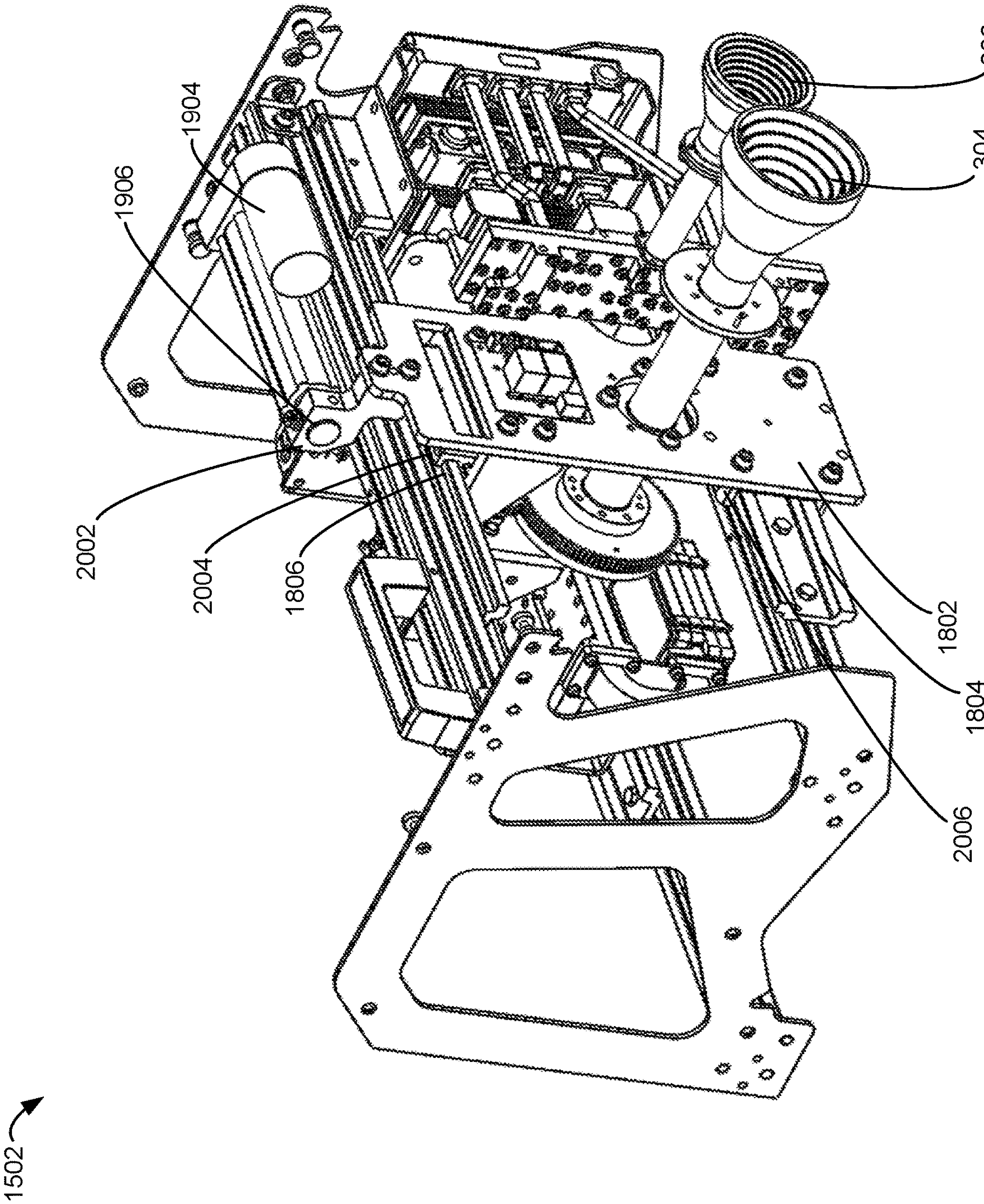

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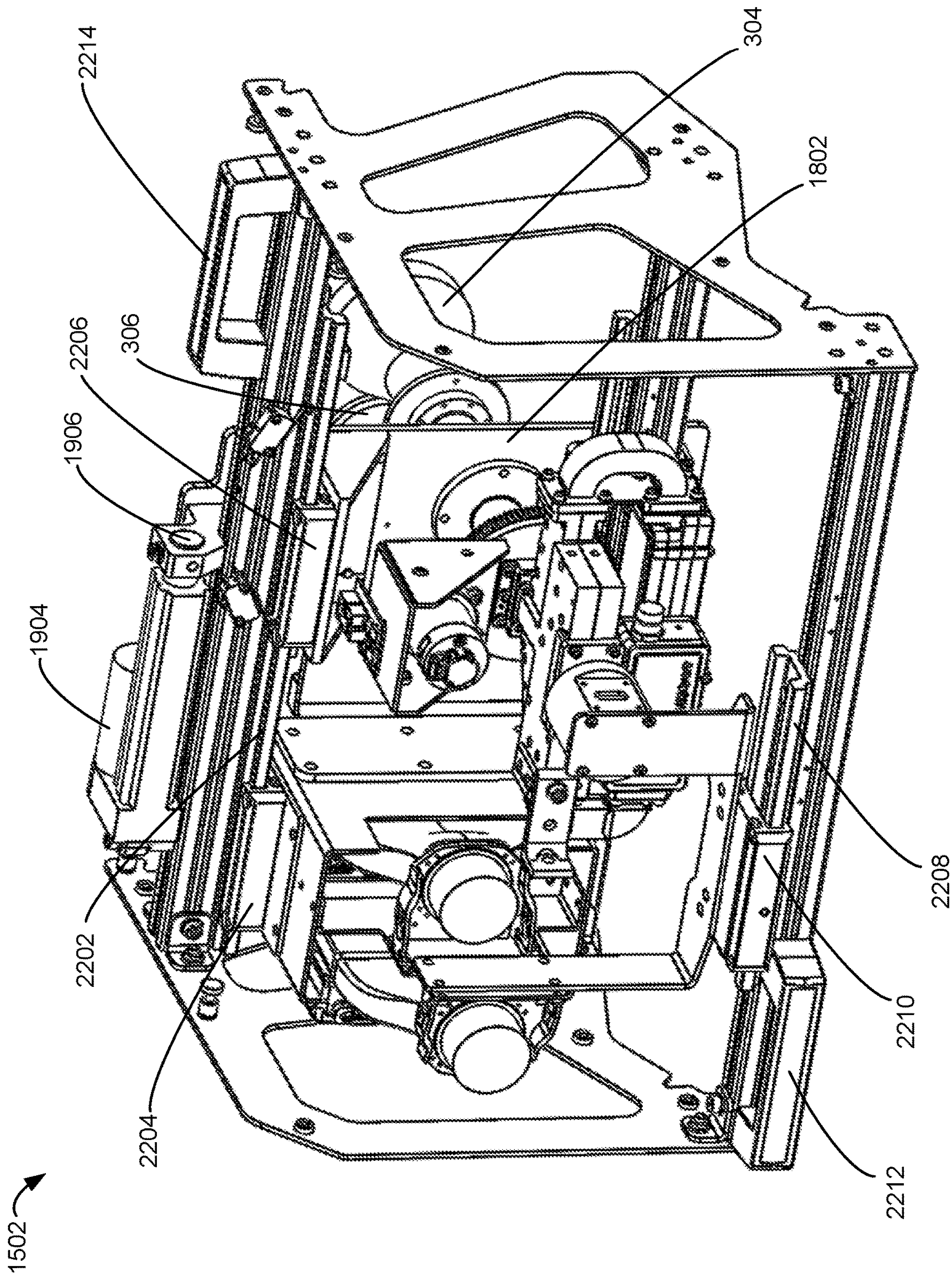
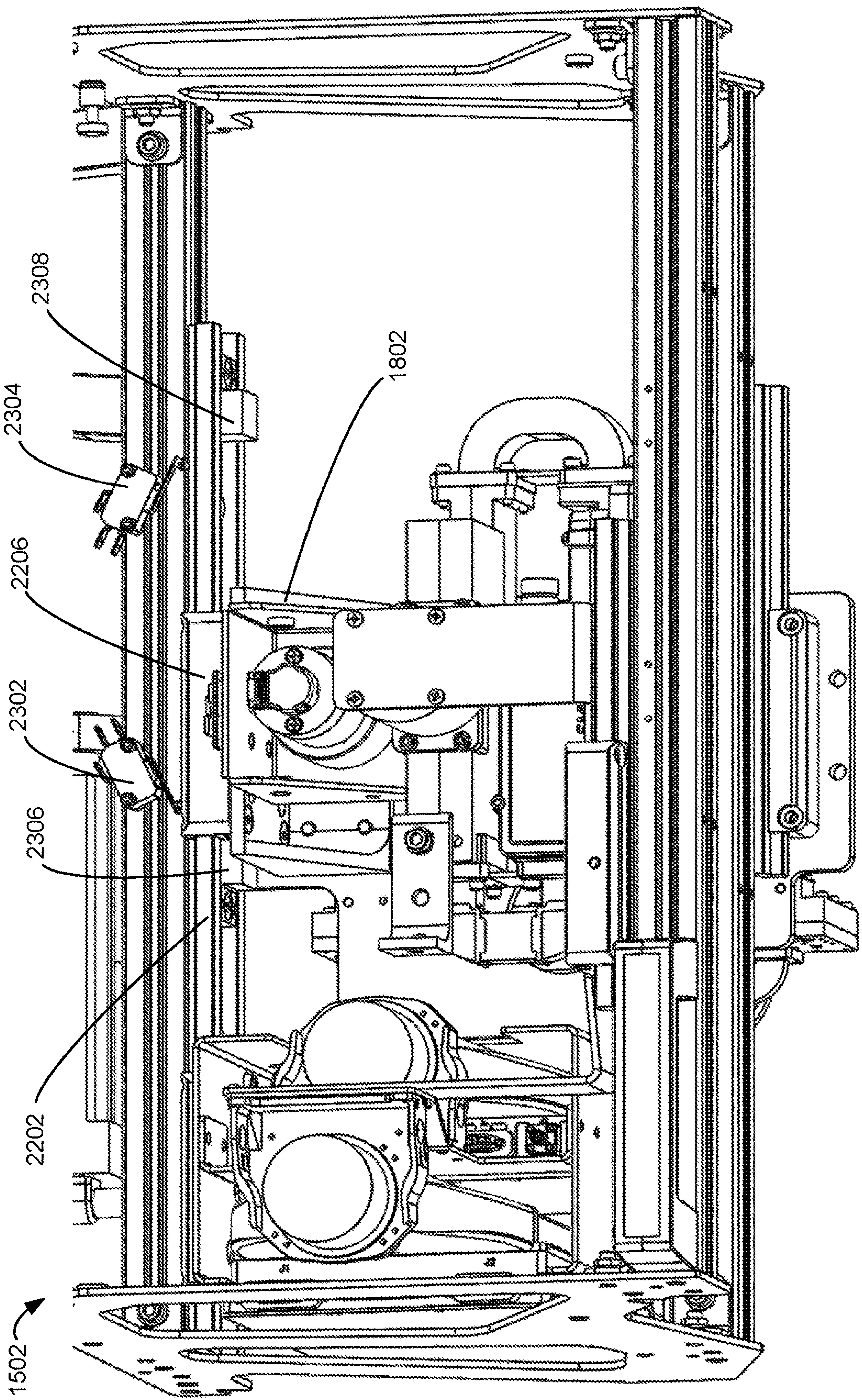

2214
304
1802
2206
306
1906
1904
2202
2204
1502
2208
2210
2212

Figure 22



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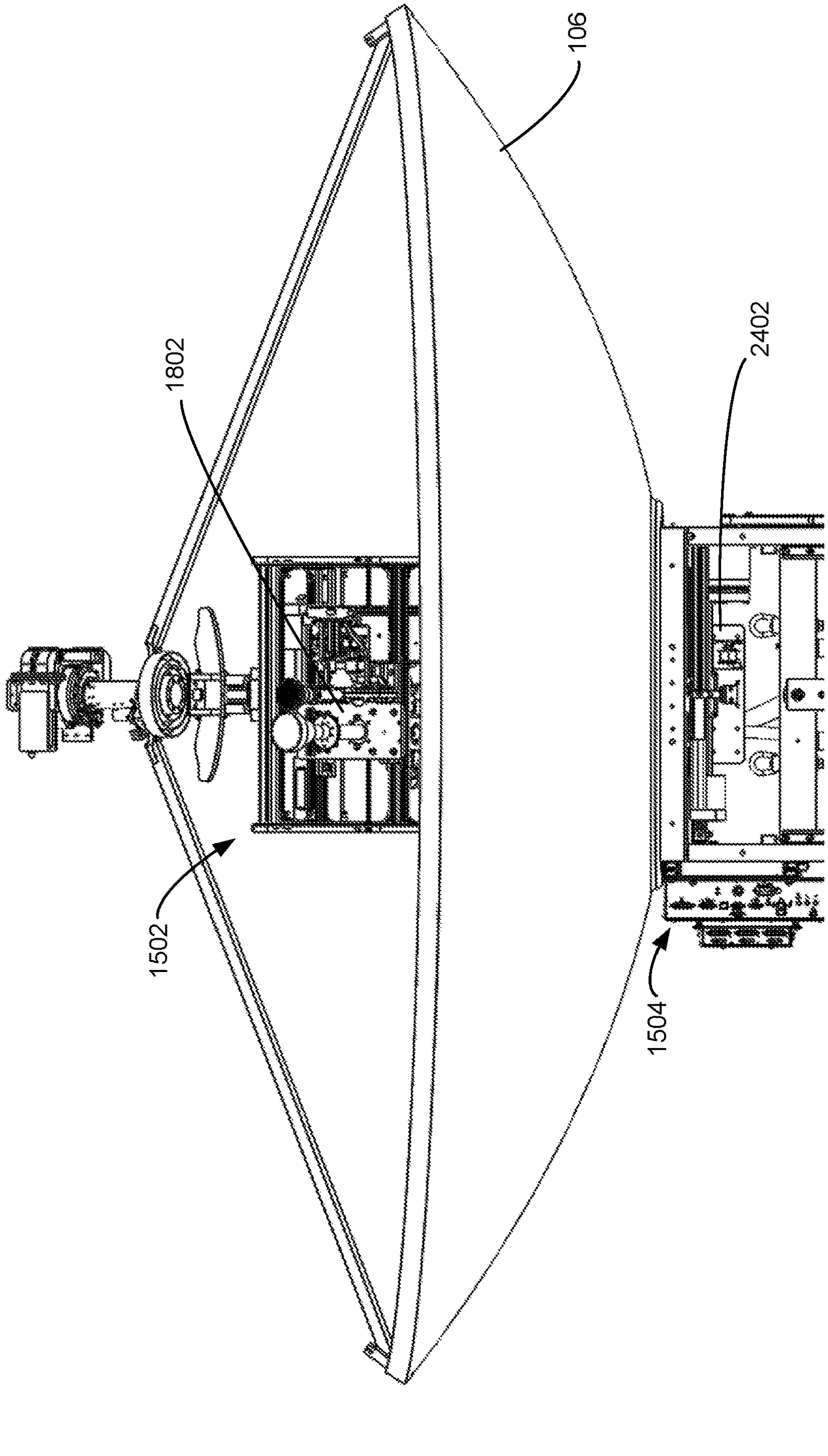

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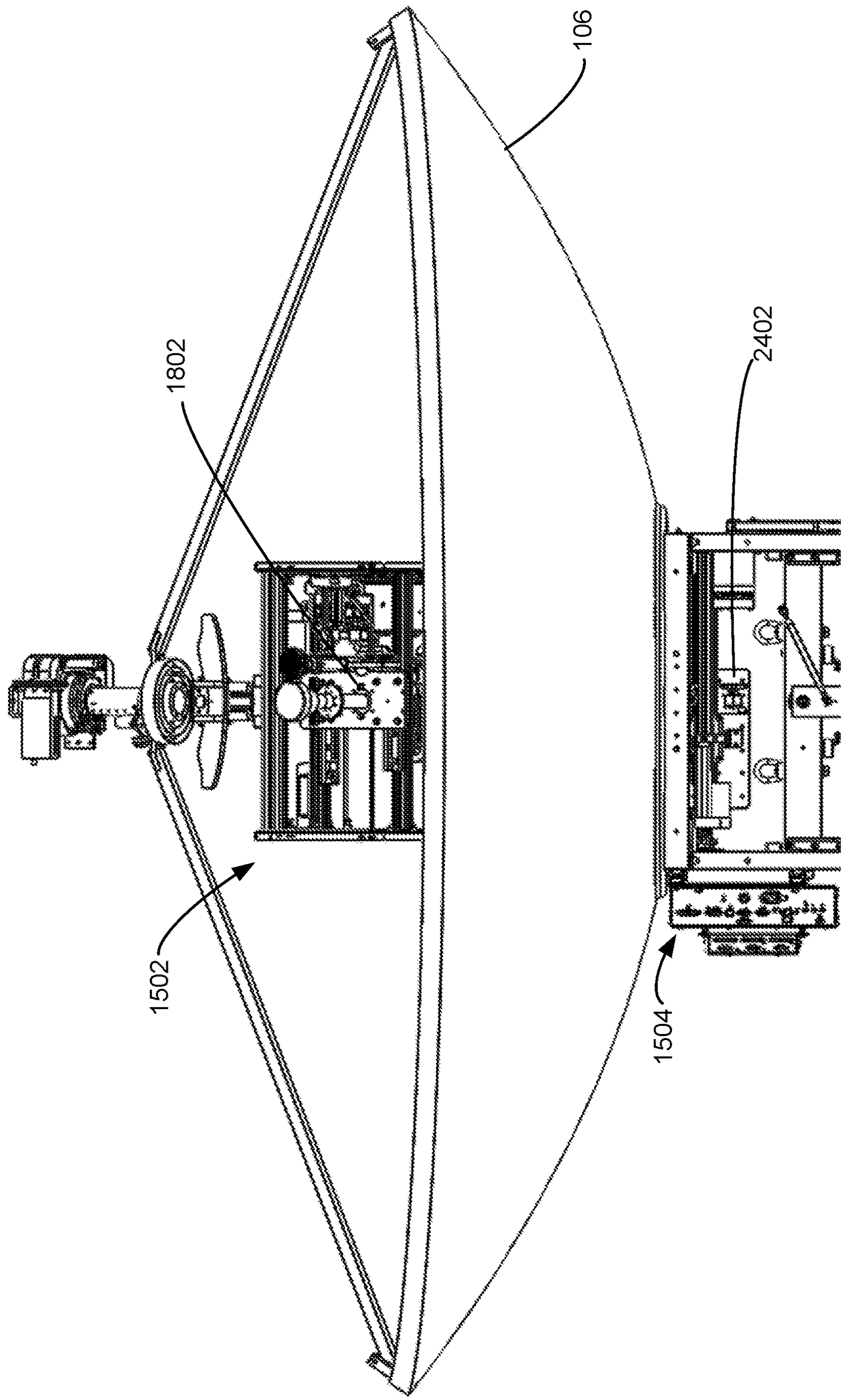

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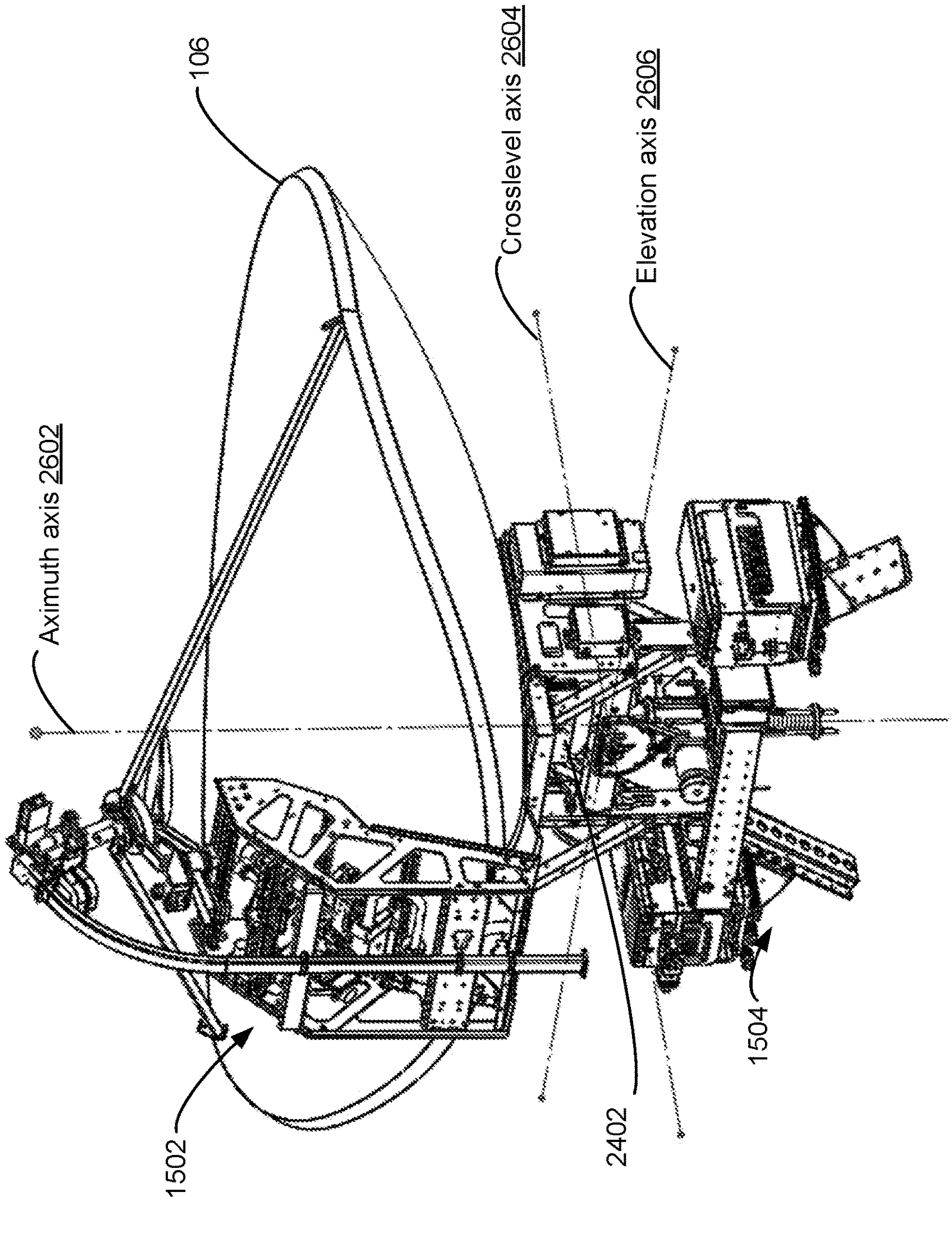
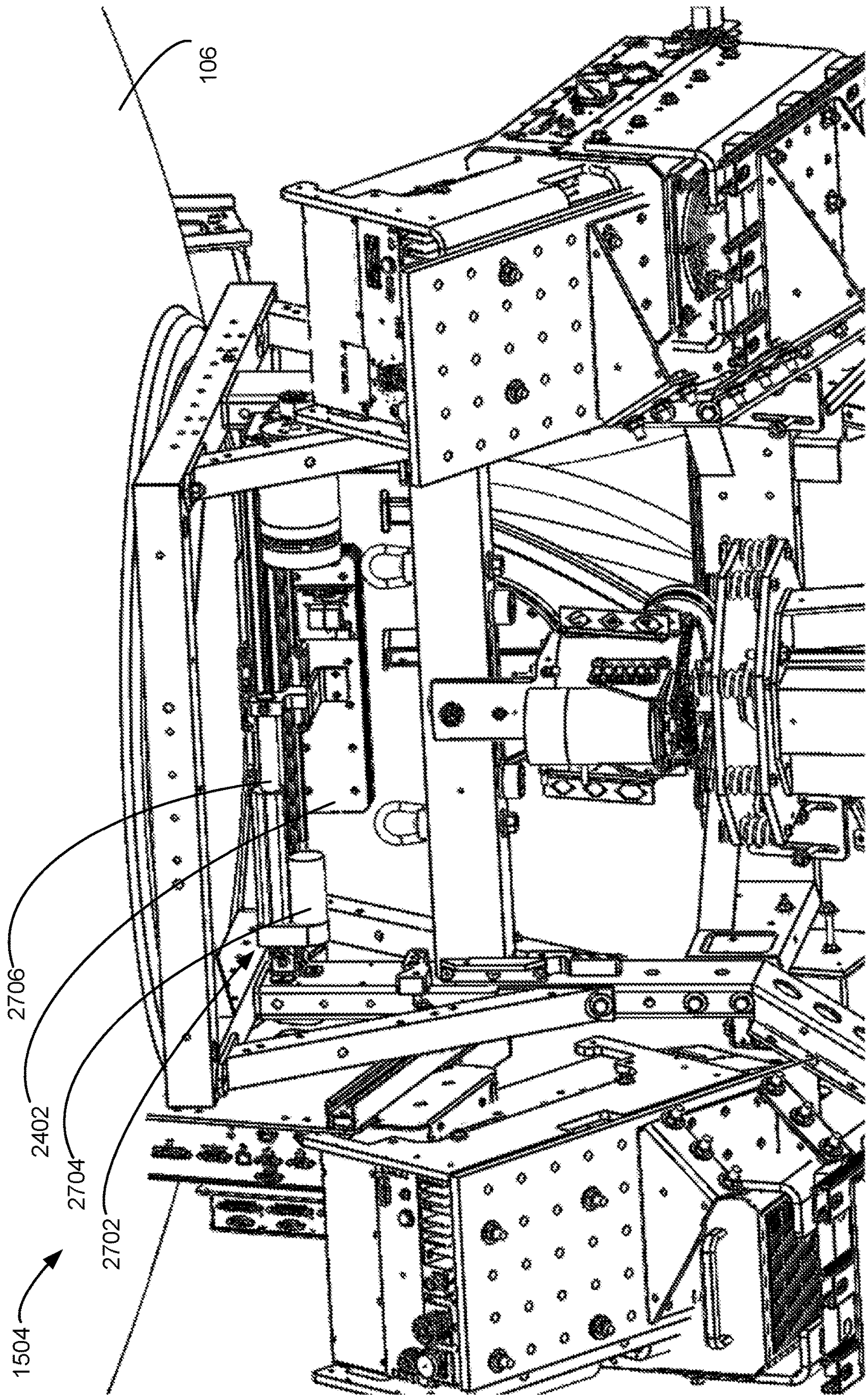

106
Crosslevel axis 2604
Elevation axis 2606
Aximuth axis 2602
1502
2402
1504

Figure 26



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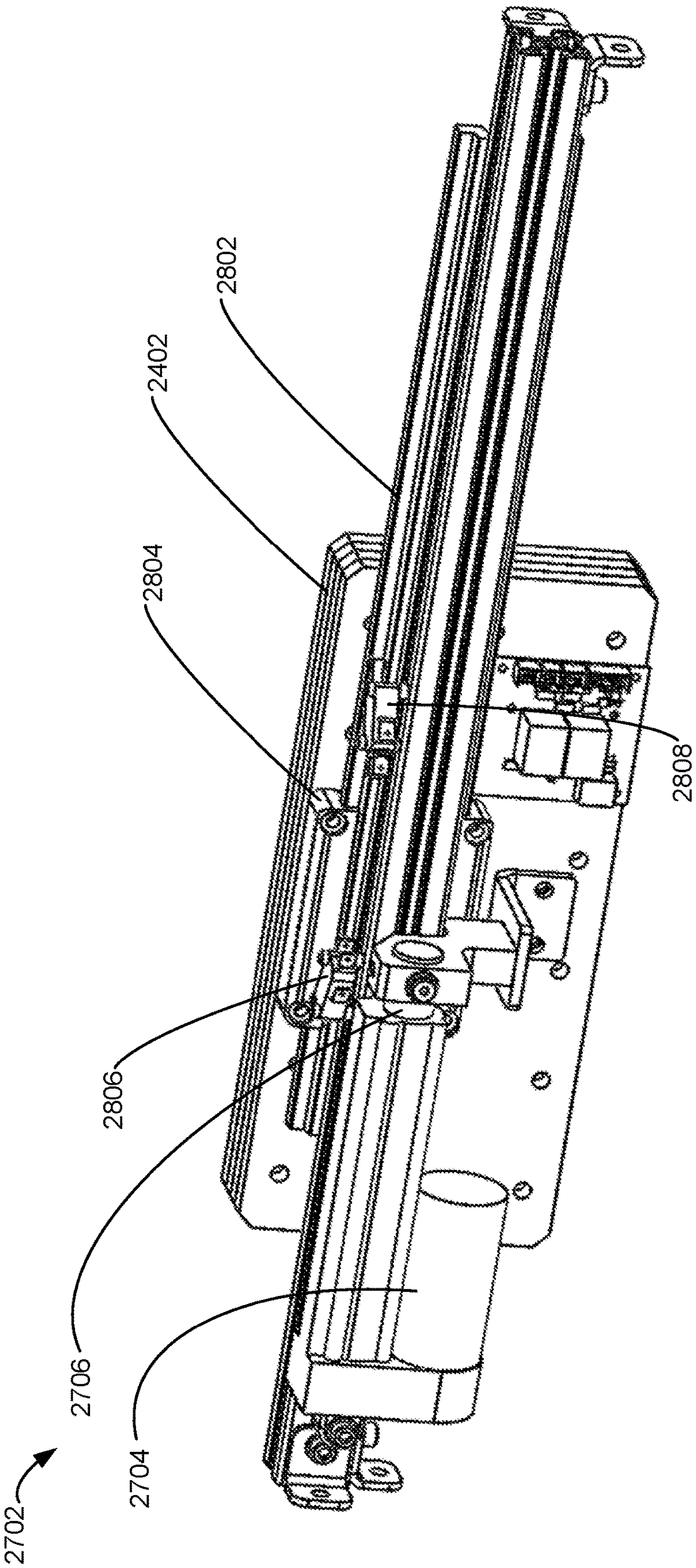

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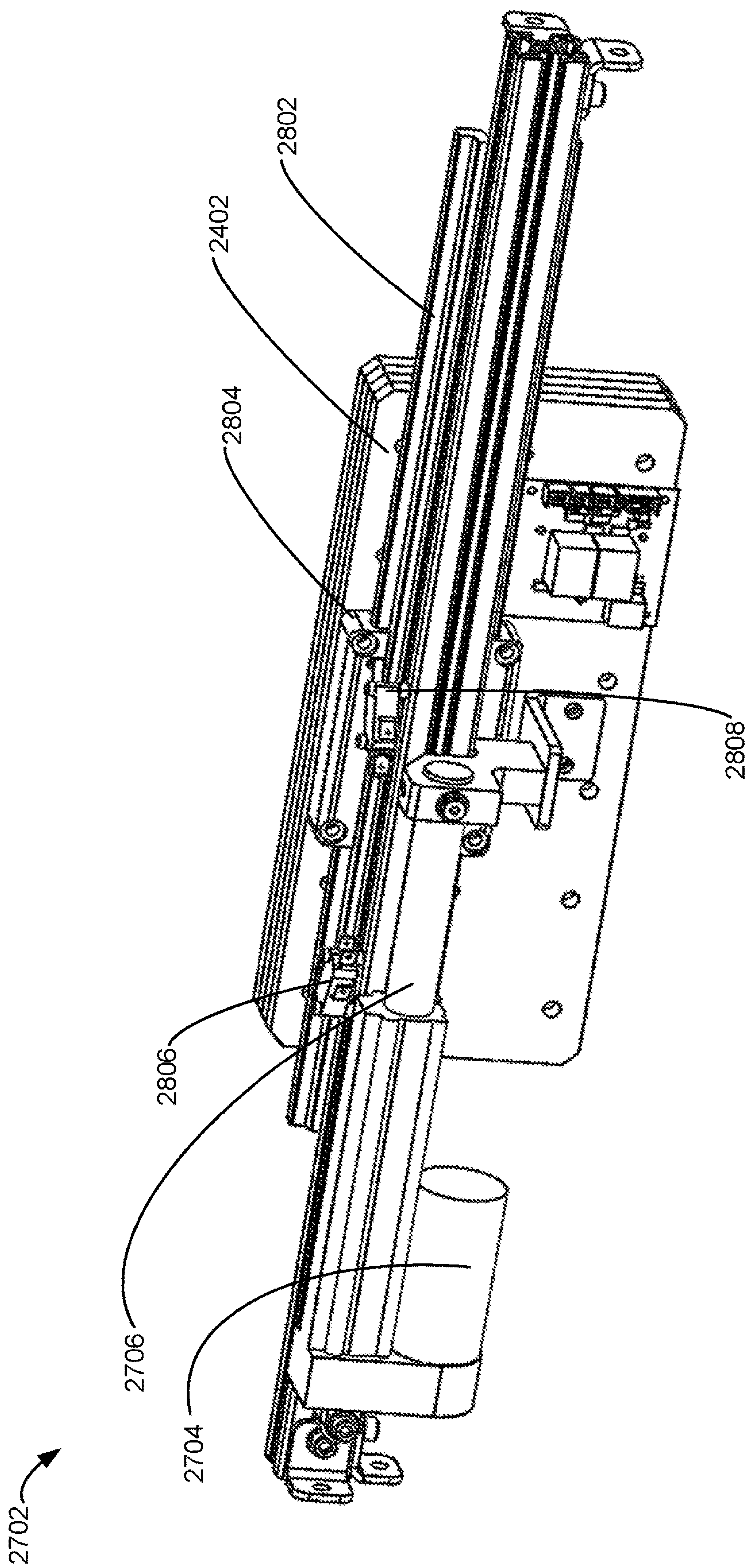

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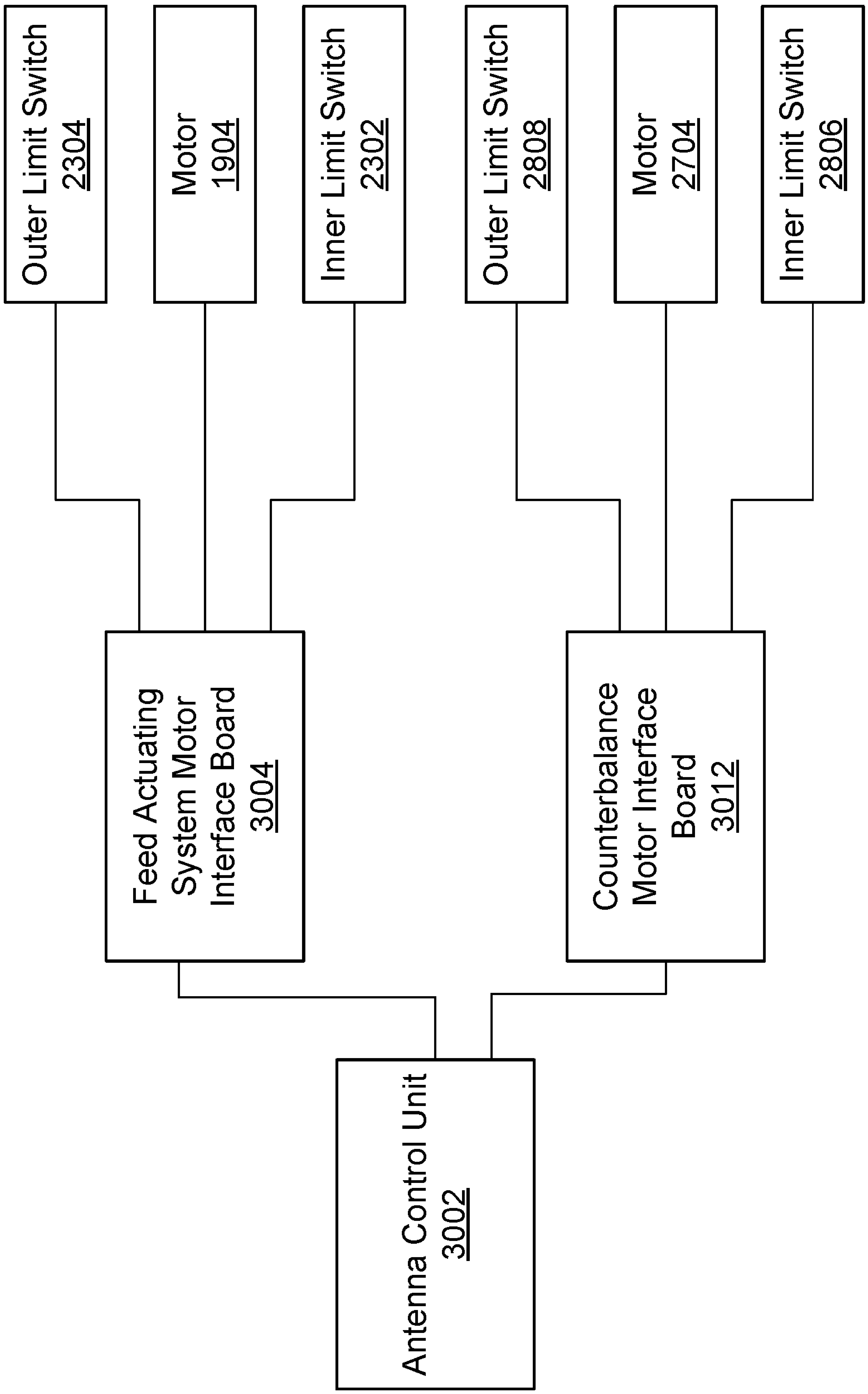

Outer Limit Switch 2304
Motor 1904
Inner Limit Switch 2302
Outer Limit Switch 2808
Motor 2704
Inner Limit Switch 2806
Feed Actuating System Motor Interface Board 3004
Counterbalance Motor Interface Board 3012
Antenna Control Unit 3002

Figure 30

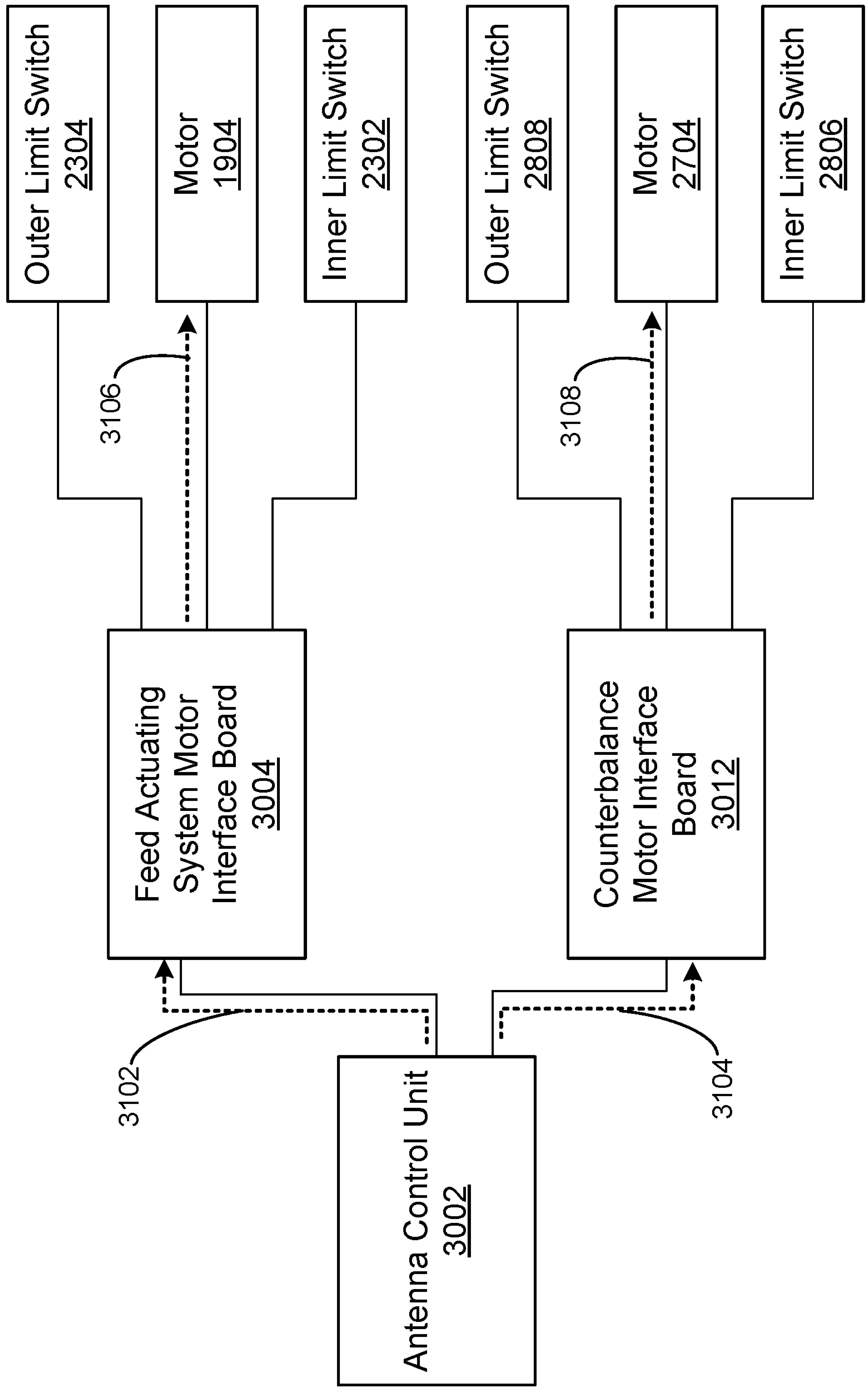

Outer Limit Switch
2304
Motor
1904
Inner Limit Switch
2302
Outer Limit Switch
2808
Motor
2704
Inner Limit Switch
2806
3106
3108
Feed Actuating System Motor Interface Board
3004
Counterbalance Motor Interface Board
3012
3102
3104
Antenna Control Unit
3002

Figure 31

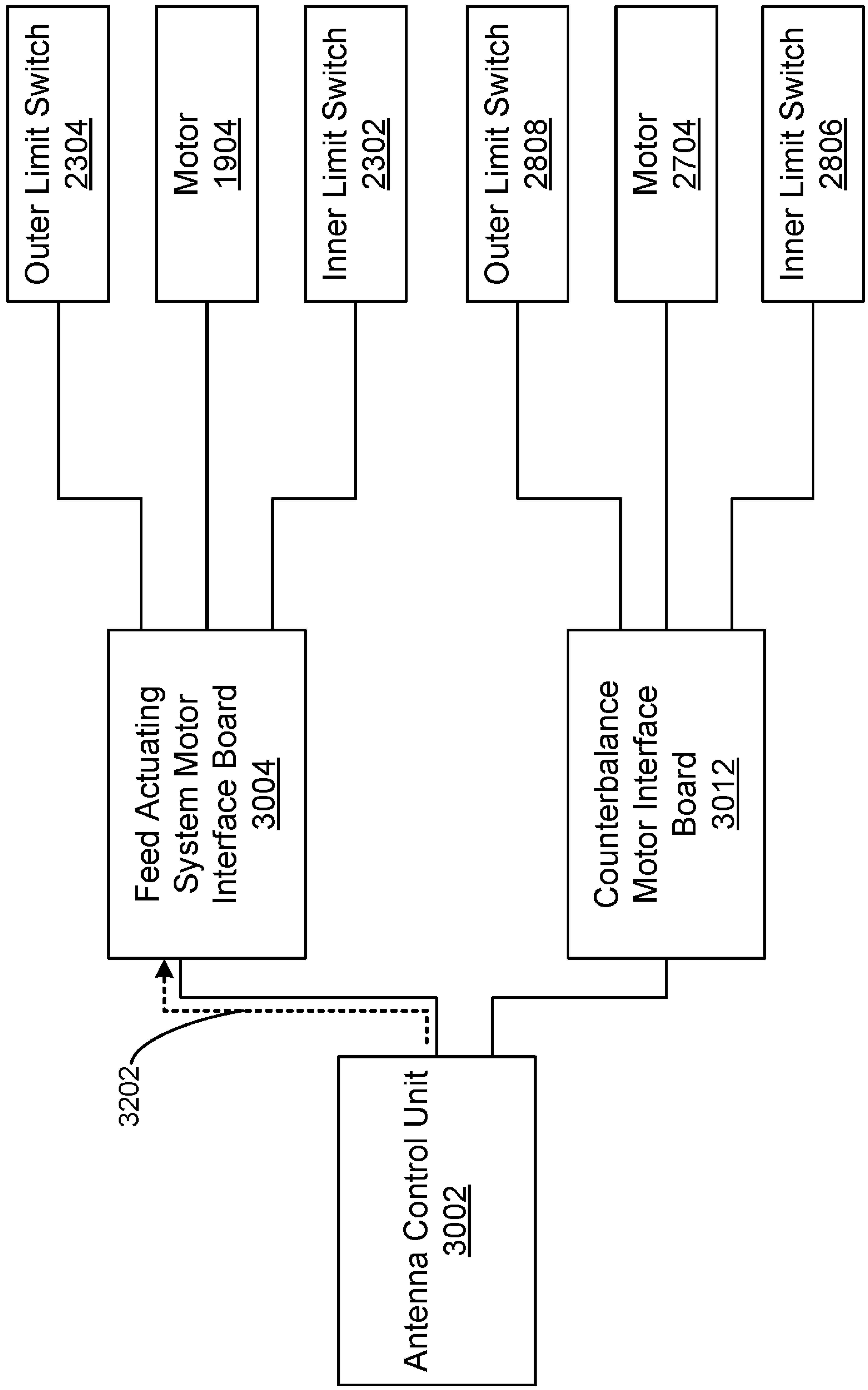
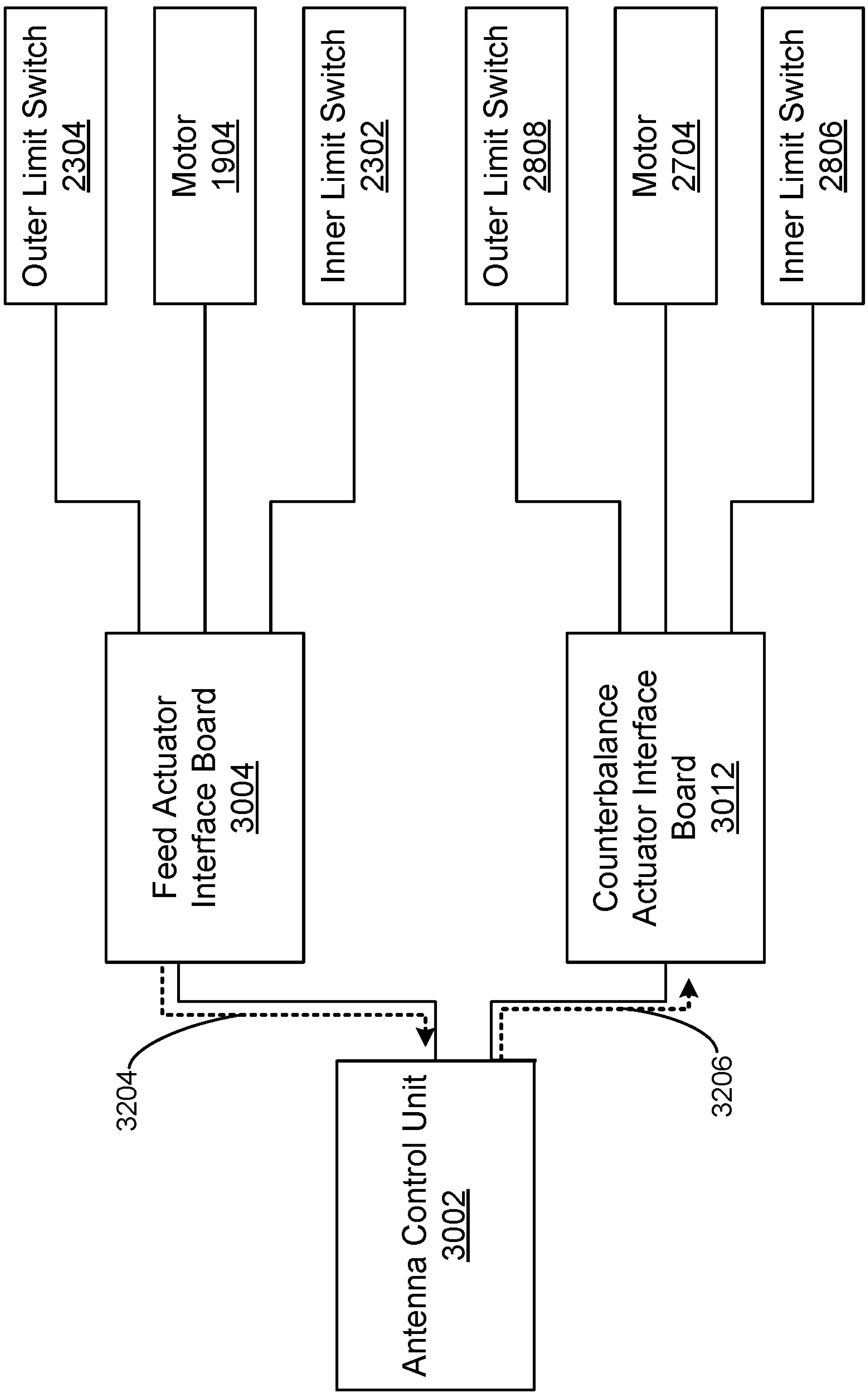
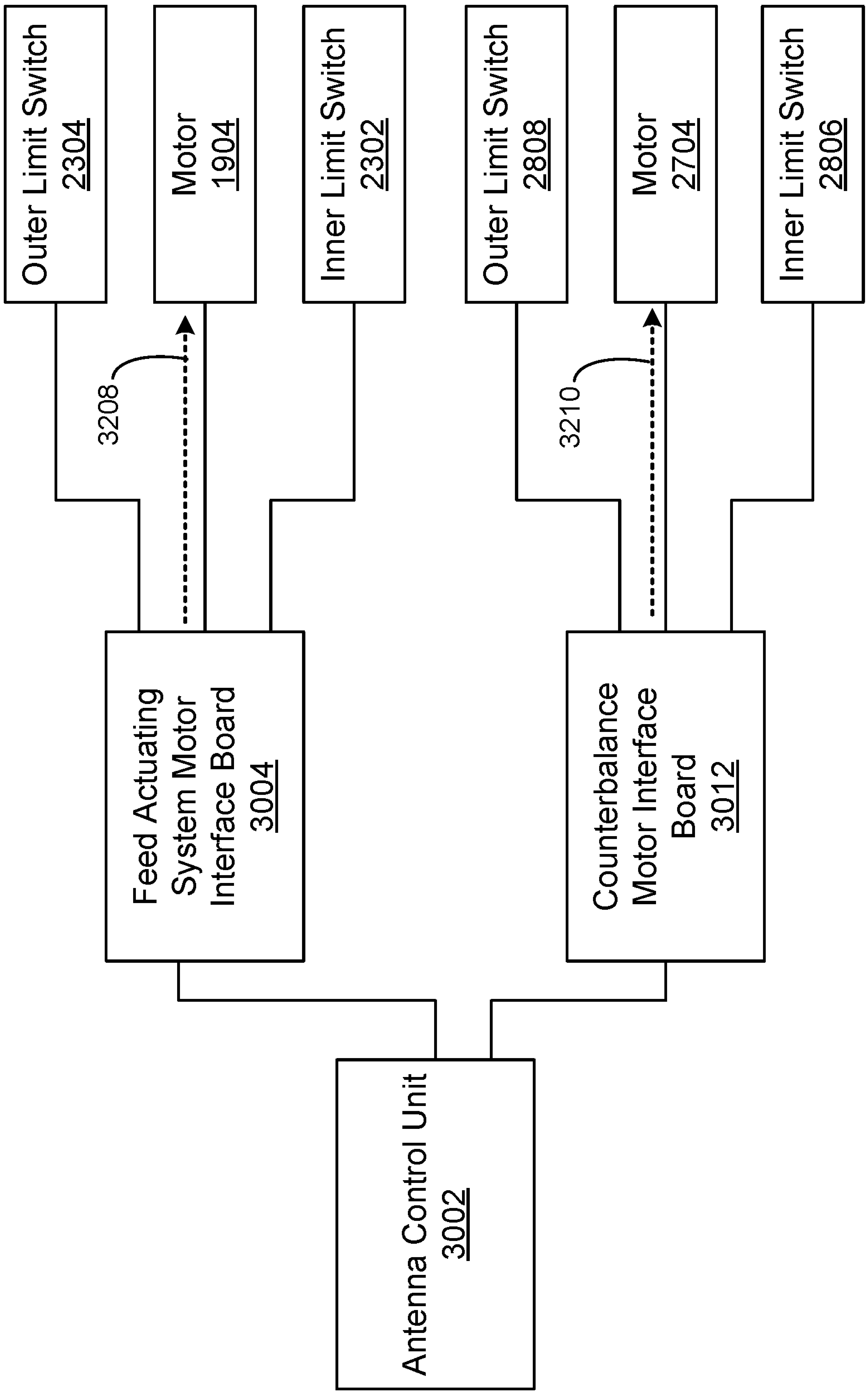

Outer Limit Switch 2304
Motor 1904
Inner Limit Switch 2302
Outer Limit Switch 2808
Motor 2704
Inner Limit Switch 2806
Feed Actuating System Motor Interface Board 3004
Counterbalance Motor Interface Board 3012
3202
Antenna Control Unit 3002

Figure 32A



Outer Limit Switch 2304
Motor 1904
Inner Limit Switch 2302
Outer Limit Switch 2808
Motor 2704
Inner Limit Switch 2806
Feed Actuator Interface Board 3004
Counterbalance Actuator Interface Board 3012
Antenna Control Unit 3002
3204
3206

Figure 32B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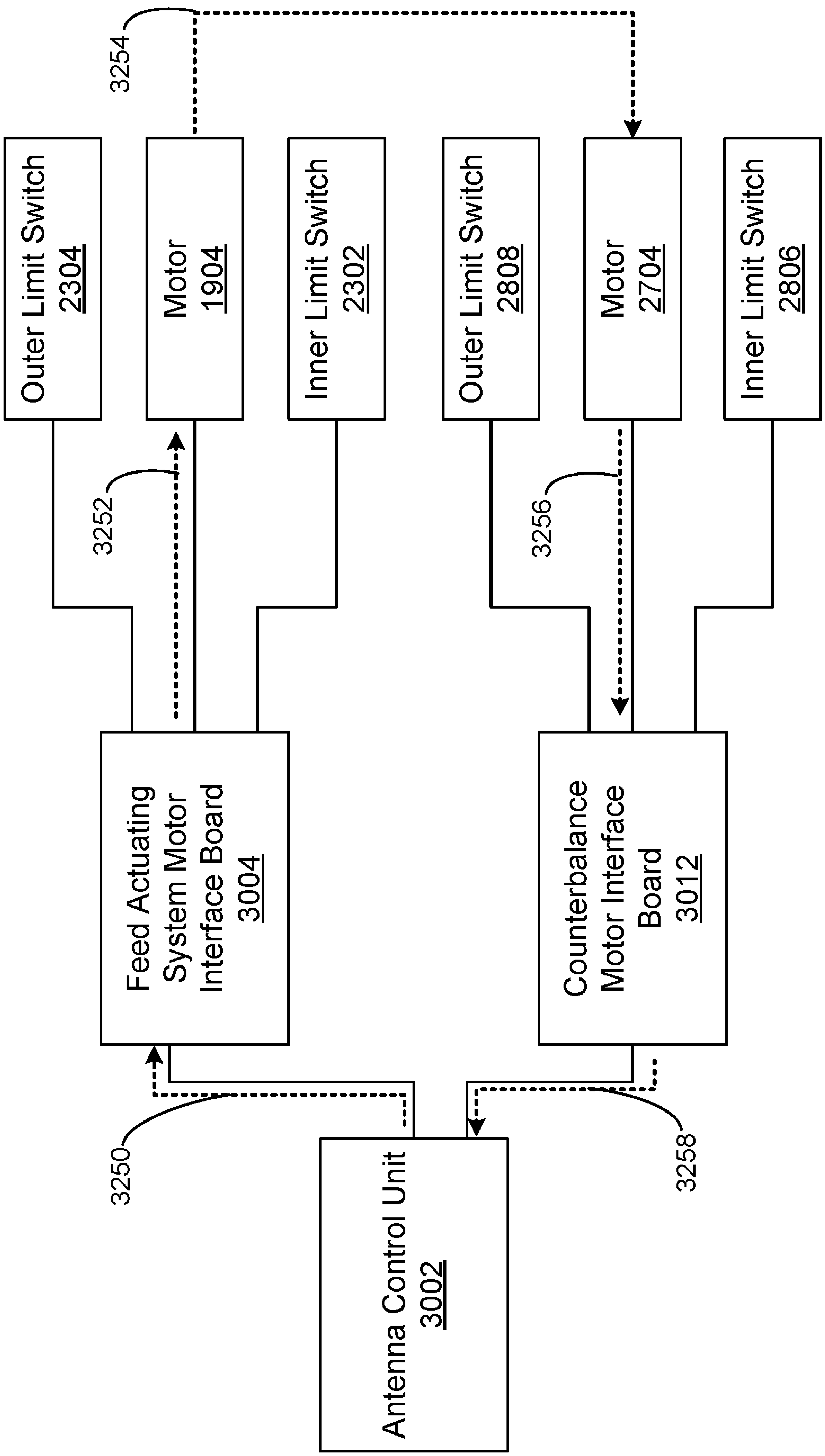
Motor
1904
Inner Limit Switch
2302
Outer Limit Switch
2808
Motor
2704
Inner Limit Switch
2806
3208
3210
Feed Actuating System Motor Interface Board
3004
Counterbalance Motor Interface Board
3012
Antenna Control Unit
3002

Figure 32C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2304
Motor
1904
Inner Limit Switch
2302
Outer Limit Switch
2808
Motor
2704
Inner Limit Switch
2806
3254
3252
3256
Feed Actuating System Motor Interface Board
3004
Counterbalance Motor Interface Board
3012
3250
3258
Antenna Control Unit
3002

Figure 32D

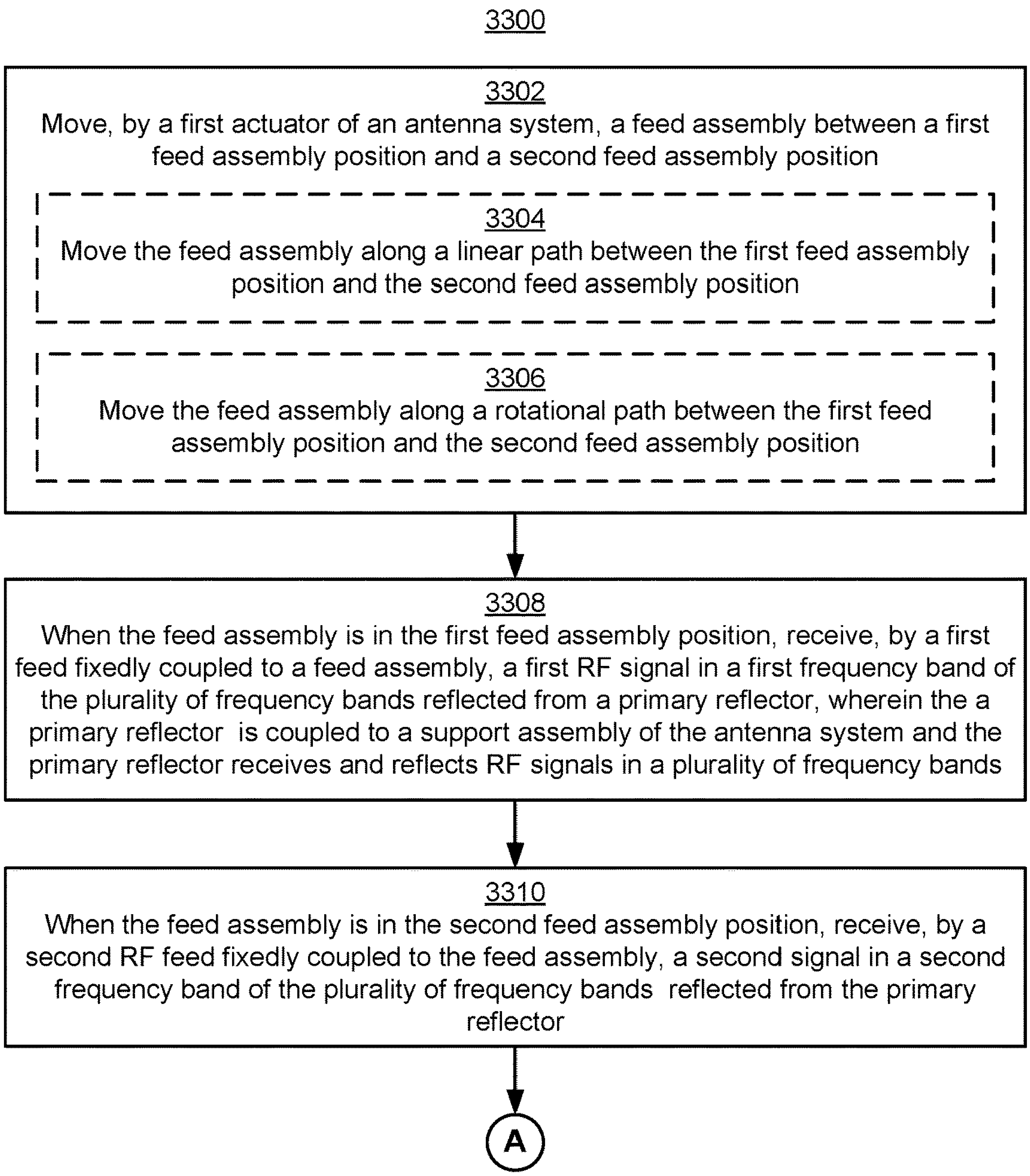
3300
3302
Move, by a first actuator of an antenna system, a feed assembly between a first feed assembly position and a second feed assembly position
3304
Move the feed assembly along a linear path between the first feed assembly position and the second feed assembly position
3306
Move the feed assembly along a rotational path between the first feed assembly position and the second feed assembly position
3308
When the feed assembly is in the first feed assembly position, receive, by a first feed fixedly coupled to a feed assembly, a first RF signal in a first frequency band of the plurality of frequency bands reflected from a primary reflector, wherein the a primary reflector is coupled to a support assembly of the antenna system and the primary reflector receives and reflects RF signals in a plurality of frequency bands
3310
When the feed assembly is in the second feed assembly position, receive, by a second RF feed fixedly coupled to the feed assembly, a second signal in a second frequency band of the plurality of frequency bands reflected from the primary reflector
A

Figure 33A

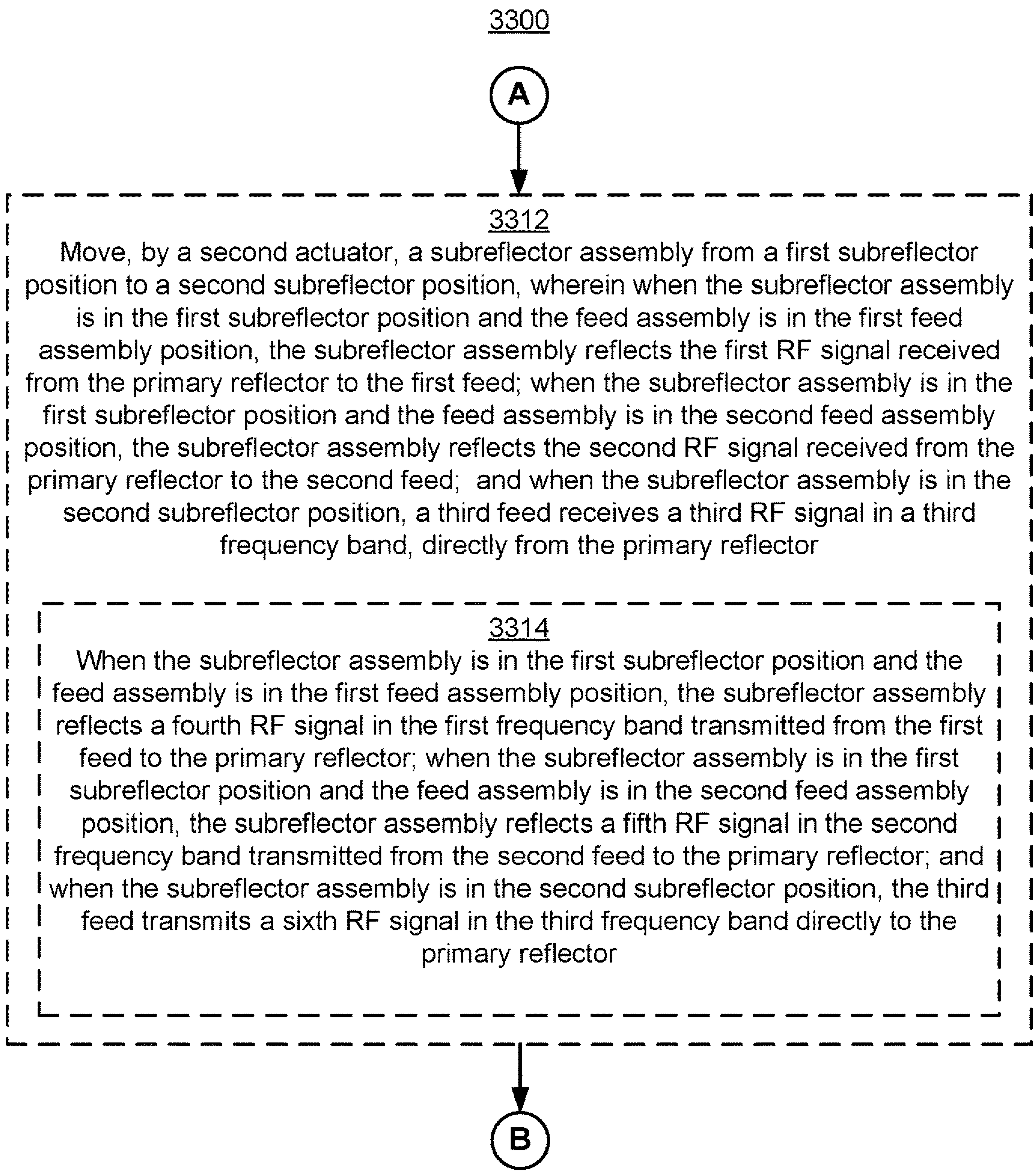
3300
A
3312
Move, by a second actuator, a subreflector assembly from a first subreflector position to a second subreflector position, wherein when the subreflector assembly is in the first subreflector position and the feed assembly is in the first feed assembly position, the subreflector assembly reflects the first RF signal received from the primary reflector to the first feed; when the subreflector assembly is in the first subreflector position and the feed assembly is in the second feed assembly position, the subreflector assembly reflects the second RF signal received from the primary reflector to the second feed; and when the subreflector assembly is in the second subreflector position, a third feed receives a third RF signal in a third frequency band, directly from the primary reflector
3314
When the subreflector assembly is in the first subreflector position and the feed assembly is in the first feed assembly position, the subreflector assembly reflects a fourth RF signal in the first frequency band transmitted from the first feed to the primary reflector; when the subreflector assembly is in the first subreflector position and the feed assembly is in the second feed assembly position, the subreflector assembly reflects a fifth RF signal in the second frequency band transmitted from the second feed to the primary reflector; and when the subreflector assembly is in the second subreflector position, the third feed transmits a sixth RF signal in the third frequency band directly to the primary reflector
B

Figure 33B

3300

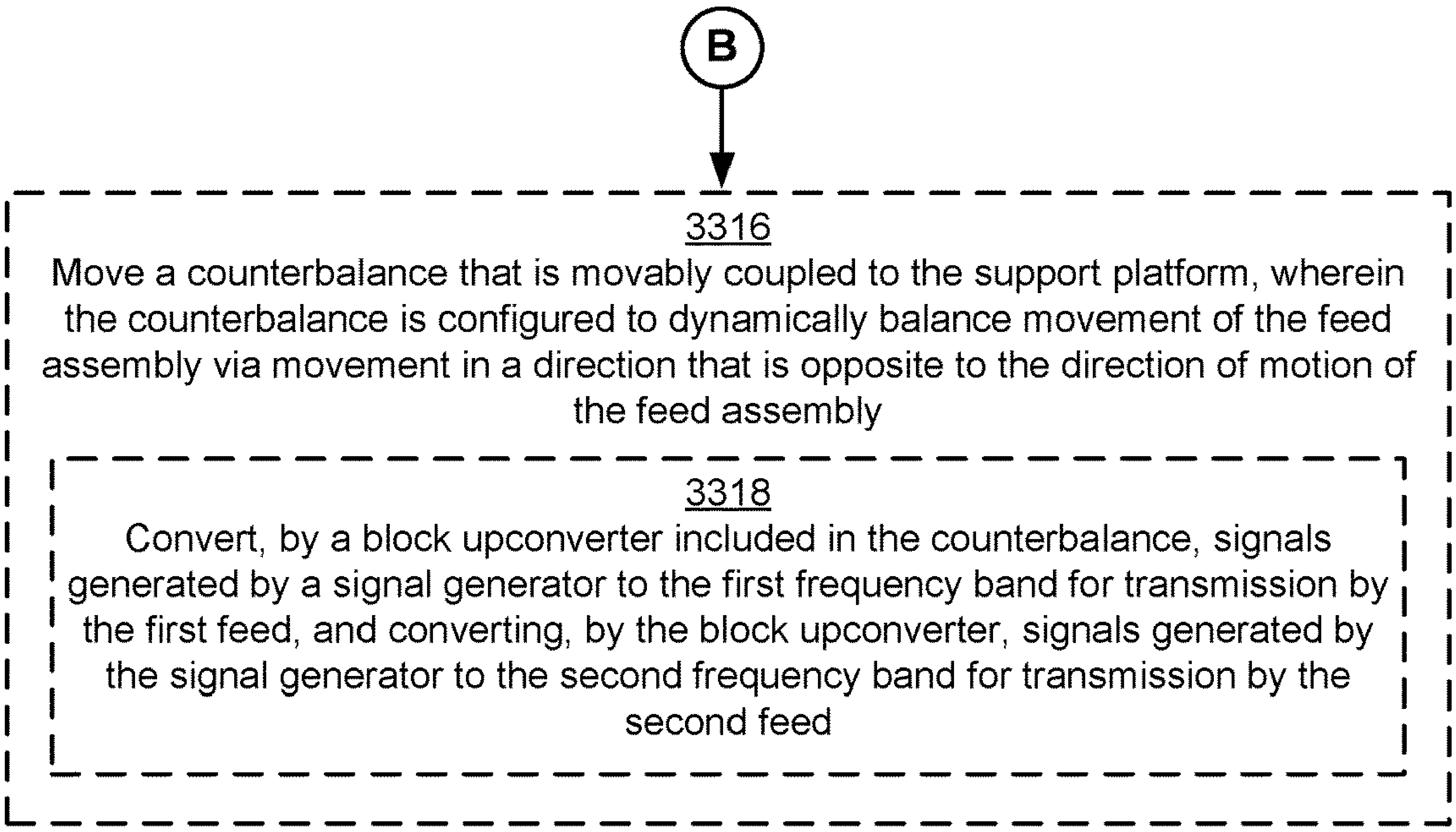

Figure 33C

ANTENNA SYSTEM WITH MULTIPLE SYNCHRONOUSLY MOVABLE FEEDS

RELATED APPLICATIONS

This application is a non-provisional application of and claims priority to U.S. Provisional Patent Application No. 62/536,602, filed Jul. 25, 2017, entitled, "Antenna System with Multiple Synchronously Movable Feeds," which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

This disclosure relates generally to multiple-feed antenna systems, and more particularly to synchronous movement of multiple feeds of a multiple-feed antenna.

BACKGROUND

Tracking antenna systems are especially suitable for use aboard ships to track communications satellites while accommodating for roll, pitch, yaw, and other motion of ships at sea. For such systems to operate effectively, they must direct one or more antennas continuously and accurately toward a communications satellite of interest.

Because different communication bands offer various advantages, there is an increasing demand for multi-band antennas capable of receiving satellite communication signals in multiple communication bands. For example, C-band signals are susceptible to terrestrial interference, while K_u-band signals are affected by weather, such as rain and ice crystals in the atmosphere. The K_a-band allows higher bandwidth communications than the C-band and the K_u-band, but is more susceptible to interference from weather, such as rain, than K_u-band signals. Accordingly, it is desirable for an antenna system to be configured for operation in multiple bands, such as the C-band, the K_u-band, and the K_a-band.

As the number of feeds included in an antenna system increases, there is a need for technology for adjusting the position of the feeds relative to a reflector to switch the feed that receives and transmits reflected signals.

SUMMARY

Without limiting the scope of the appended claims, after considering this disclosure, and particularly after considering the section entitled "Detailed Description," one will understand how the aspects of various embodiments are used to determine when a tracked user device is not at an indicated area.

In some embodiments, an antenna system for communicating signals having radio frequencies in a plurality of radio frequency (RF) bands includes a support assembly, a primary reflector that is coupled to the support assembly, a feed assembly that is movably coupled to the support assembly, a first feed fixedly coupled to the feed platform, and a second feed fixedly coupled to the feed platform. The primary reflector is configured to receive and reflect RF signals in the plurality of frequency bands. The first feed is configured to communicate RF signals in a first frequency band of the plurality of frequency bands. The second feed is configured to communicate RF signals in a second frequency band of the plurality of frequency bands. The antenna system also includes a first actuator that is configured to move the feed assembly from a first feed assembly position, where the first feed is positioned along a first signal path with the primary reflector, to a second feed assembly position, where the second feed is positioned along a second signal path with the primary reflector.

In some embodiments, the antenna system includes a third feed fixedly coupled to the support assembly. The third feed is configured to communicate RF signals in a third frequency band of the plurality of frequency bands. The antenna system also includes a subreflector movably coupled to the support assembly, wherein the subreflector is movable, by a second actuator, between a first subreflector position and a second subreflector position, and wherein the antenna system is configured such that: when the subreflector assembly is in the first subreflector position and the feed assembly is in the first feed assembly position, the subreflector assembly is positioned along the first signal path to reflect RF signals in the first frequency band between the primary reflector and the first feed; when the subreflector assembly is in the first subreflector position and the feed assembly is in the second feed assembly position, the subreflector assembly is positioned along the second signal path to reflect RF signals in the second frequency band between the primary reflector and the second feed; and when the subreflector assembly is in the second subreflector position, the third feed is positioned to receive RF signals in a third frequency band of the plurality of frequency bands directly from the primary reflector.

In some embodiments, when the subreflector assembly is in the first subreflector position, the subreflector assembly intersects at least one of the first signal path or the second signal path.

In some embodiments, the antenna system is configured such that: when the feed assembly is in the first feed assembly position, the second feed is not positioned to communicate RF signals in the second frequency band; and when the feed assembly is in the second feed assembly position, the first feed is not positioned to communicate RF signals in the first frequency band.

In some embodiments, the first actuator includes a first motor that is configured to drive a first lead screw and the first lead screw is coupled to the feed assembly, such that the driving of the first lead screw causes movement of the feed assembly.

In some embodiments, the antenna system includes a counterbalance that is movably coupled to the support assembly. The counterbalance is configured to dynamically balance movement of the feed assembly via movement in a direction that is opposite to the direction of motion of the feed assembly.

In some embodiments, the counterbalance includes a plurality of weight components.

In some embodiments, the counterbalance includes a block upconverter configured to convert signals generated by a signal generator to signals having frequencies in the first frequency band for transmission by the first feed and convert signals generated by the signal generator to signals having frequencies in the second frequency band for transmission by the second feed.

In some embodiments, the first actuator is a first motor that is configured to drive a rotatable shaft and the antenna system includes a second motor that is configured to drive the counterbalance.

In some embodiments, the first actuator is a motor that is configured to drive a rotatable shaft; the rotatable shaft is coupled to a first connector assembly configured to drive the feed assembly; and the rotatable shaft is coupled to a second connector assembly configured to drive the counterbalance.

In some embodiments, a third actuator includes a second motor that is configured to drive a second lead screw and the second lead screw is coupled to the counterbalance, such that the driving of the second lead screw causes movement of the counterbalance.

In some embodiments, the first actuator is a first motor and a third actuator is a second motor connected in series with the first motor. The third actuator is configured to move the counterbalance from a first counterbalance position to a second counterbalance position. In some embodiments, a condition of the first motor that affects operation of the first motor causes, via the serial connection between the first motor and the second motor, operation of the second motor to be altered such that balance between the feed assembly and the counterbalance is maintained.

In some embodiments, the first actuator is a first solenoid that is coupled to the feed assembly. In some embodiments, the antenna system includes a second solenoid that is coupled to the counterbalance.

In some embodiments, the primary reflector is positioned between the feed assembly and the counterbalance.

In some embodiments, a first rubberized waveguide is coupled to the first feed and configured to receive the first RF signal from the first feed and a second rubberized waveguide I coupled to the second feed and configured to receive the second RF signal from the second feed.

In some embodiments, the feed assembly moves along a linear path between the first feed assembly position and the second feed assembly position.

In some embodiments, the feed assembly moves along a rotational path between the first feed assembly position and the second feed assembly position.

In some embodiments, a method for receiving signals having frequencies in a plurality of radio frequency (RF) frequency ranges is implemented at an antenna system that includes: a support assembly; a primary reflector that is coupled to the support assembly, wherein the primary reflector receives and reflects RF signals in a plurality of frequency bands; a feed assembly that is movably coupled to the support assembly; a first actuator configured to move the feed assembly; a first feed fixedly coupled to the feed assembly; and a second feed fixedly coupled to the feed assembly. The method includes moving, by the first actuator, the feed assembly between a first feed assembly position and a second feed assembly position. The method also includes, when the feed assembly is in the first feed assembly position, receiving, by the first feed, a first RF signal in a first frequency band of the plurality of frequency bands reflected from the primary reflector. The method also includes, when the feed assembly is in the second feed assembly position, receiving, by the second RF feed, a second signal in a second frequency band of the plurality of frequency bands reflected from the primary reflector.

In some embodiments, the method includes moving, by a second actuator, a subreflector assembly from a first subreflector position to a second subreflector position. When the subreflector assembly is in the first subreflector position and the feed assembly is in the first feed assembly position, the subreflector assembly reflects the first RF signal received from the primary reflector to the first feed. When the subreflector assembly is in the first subreflector position and the feed assembly is in the second feed assembly position, the subreflector assembly reflects the second RF signal received from the primary reflector to the second feed. When the subreflector assembly is in the second subreflector position, a third feed receives a third RF signal in a third frequency band, directly from the primary reflector.

In some embodiments, when the subreflector assembly is in the first subreflector position and the feed assembly is in the first feed assembly position, the subreflector assembly reflects a fourth RF signal in the first frequency band transmitted from the first feed to the primary reflector. When the subreflector assembly is in the first subreflector position and the feed assembly is in the second feed assembly position, the subreflector assembly reflects a fifth RF signal in the second frequency band transmitted from the second feed to the primary reflector. When the subreflector assembly is in the second subreflector position, the third feed transmits a sixth RF signal in the third frequency band directly to the primary reflector.

In some embodiments, the method includes moving a counterbalance that is movably coupled to the support assembly. The counterbalance is configured to dynamically balance movement of the feed assembly via movement in a direction that is opposite to the direction of motion of the feed assembly.

In some embodiments, the method includes converting, by a block upconverter included in the counterbalance, signals generated by a signal generator to the first frequency band for transmission by the first feed. In some embodiments, the method includes converting, by the block upconverter, signals generated by the signal generator to the second frequency band for transmission by the second feed.

In some embodiments, the method includes moving the feed assembly along a linear path between the first feed assembly position and the second feed assembly position.

In some embodiments, the method includes moving the feed assembly along a rotational path between the first feed assembly position and the second feed assembly position.

In some embodiments, an antenna system for receiving signals having frequencies in a plurality of radio frequency (RF) frequency bands includes support means for supporting a primary reflector, wherein the primary reflector receives and reflects RF signals in a plurality of frequency bands; a feed assembly that is movably coupled to the support means; a first signal receiving means fixedly coupled to the feed assembly; a second signal receiving means fixedly coupled to the feed assembly; and means for moving the feed assembly from a first feed assembly position, where the first feed is positioned to receive a first RF signal in a first frequency band of the plurality of frequency bands from the primary reflector, to a second feed assembly position, where the second feed is positioned to receive a second RF signal in a second frequency band of the plurality of frequency bands from the primary reflector.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the present disclosure can be understood in greater detail, a more particular description may be had by reference to the features of various embodiments, some of which are illustrated in the appended drawings. The appended drawings, however, merely illustrate pertinent features of the present disclosure and are therefore not to be considered limiting, for the description may admit to other effective features.

FIG. **1** is a front perspective view of an antenna system for receiving signals having radio frequencies in a plurality of radio frequency (RF) ranges, in accordance with some embodiments.

FIG. **2** is a side view of the antenna system shown in FIG. **1**, in accordance with some embodiments.

FIGS. **3-4** illustrate movement of the subreflector assembly of the antenna system shown in FIGS. **1** and **2** between a first position and a second position, in accordance with some embodiments.

FIG. **5** is an enlarged perspective view of a feed subsystem, a subreflector assembly, and a fixed feed of an antenna system of the antenna system shown in FIGS. **1-4**, in accordance with some embodiments.

FIG. **6** is a top perspective view of a movable feed sub-system of the antenna system shown in FIGS. **1-5**, in accordance with some embodiments

FIGS. **7-8** are bottom perspective views of movable feed sub-system of the antenna system shown FIGS. **1-6**, illustrating movement of a movable platform from a first position to a second position, in accordance with some embodiments.

FIGS. **9-10** are bottom perspective views of a movable feed support bracket of a movable feed sub-system of the antenna system shown in FIGS. **1-8**, illustrating movement of a movable feed platform from a first position to a second position, in accordance with some embodiments.

FIG. **11** is a signal path schematic illustrating a signal path between a first movable feed and a primary reflector, in accordance with some embodiments.

FIG. **12** is a signal path schematic illustrating a signal path between a second movable feed and a primary reflector, in accordance with some embodiments.

FIG. **13** is a signal path schematic illustrating a signal path between a fixed feed and a primary reflector, in accordance with some embodiments.

FIG. **14** is a block diagram illustrating an actuating system to cause movement of movable feed platform and a counterbalance, in accordance with some embodiments.

FIG. **15** is side view of an antenna system for receiving signals having radio frequencies in a plurality of radio frequency (RF) frequency ranges, in accordance with some embodiments.

FIGS. **16-17** illustrate movement of the subreflector assembly of the antenna system shown in FIG. **15** between a first position and a second position, in accordance with some embodiments.

FIG. **18** is an enlarged perspective view of a movable feed sub-system, in accordance with some embodiments.

FIG. **19** is an enlarged perspective view of a linear actuator of a movable feed sub-system, in accordance with some embodiments.

FIGS. **20-21** are enlarged front perspective views of a movable feed sub-system that illustrate movement of a movable feed assembly between a first position and a second position, in accordance with some embodiments.

FIG. **22** illustrates an enlarged rear perspective view of a movable feed sub-system, in accordance with some embodiments.

FIG. **23** illustrates an enlarged rear elevation view of a movable feed sub-system, in accordance with some embodiments.

FIGS. **24-25** illustrate movement of movable feed assembly of a movable feed sub-system and corresponding movement of counterbalance of counterbalance sub-system, in accordance with some embodiments.

FIG. **26** is a perspective view of a movable feed subsystem and a counterbalance of a counterbalance sub-system relative to a set of axes, in accordance with some embodiments.

FIG. **27** is an enlarged view of a counterbalance subsystem, in accordance with some embodiments.

FIGS. **28-29** illustrate movement of a counterbalance between a first position and a second position by a linear actuator system, in accordance with some embodiments.

FIG. **30** is a system diagram of an antenna control unit, in accordance with some embodiments.

FIG. **31** illustrates parallel operation of a feed assembly motor and a counterbalance motor, in accordance with some embodiments.

FIGS. **32**A-**32**D illustrate serial operation of a feed assembly motor and a counterbalance motor, in accordance with some embodiments.

FIGS. **33**A-**33**C are flow charts illustrating a method for receiving signals having frequencies in a plurality of radio frequency (RF) ranges, in accordance with some embodiments.

In accordance with common practice, some of the drawings may not depict all of the components of a given system, method or device. Finally, like reference numerals may be used to denote like features throughout the specification and figures.

DETAILED DESCRIPTION

Numerous details are described herein in order to provide a thorough understanding of the example embodiments illustrated in the accompanying drawings. However, some embodiments may be practiced without many of the specific details, and the scope of the claims is only limited by those features and aspects specifically recited in the claims. Furthermore, well-known processes, components, and materials have not been described in exhaustive detail so as not to unnecessarily obscure pertinent aspects of the embodiments described herein.

FIG. **1** shows a front perspective view of an antenna system **100** for receiving signals having radio frequencies in a plurality of radio frequency (RF) frequency ranges, in accordance with some embodiments. In some embodiments, antenna system **100** is enclosed within a radome **102** (shown cut away to show antenna system **100**). In some embodiments, radome **102** is mounted on a base **103**. Radome **102** protects antenna system **100** from exposure to adverse conditions such as sun, inclement weather, etc. while antenna system **100** is mounted outdoors (e.g., on a ship or other moving vessel).

Antenna system **100** includes a primary reflector **106** (e.g., a parabolic reflector) coupled to a support assembly **104**. In some embodiments, the support assembly **104** is mounted on base **103**. In some embodiments, primary reflector **106** is configured to reflect (to or from a satellite) RF signals in a plurality of frequency bands (for example, the C-band (e.g., 4-8 GHz), the K_u-band (e.g., 12-18 GHz), and/or the Ka-band (e.g., 26.5-40 GHz)).

Antenna system **100** includes a subreflector assembly **108** that is movably coupled to support assembly **104**. For example, subreflector assembly **108** is movably coupled to a support sub-assembly **110** of support assembly **104**. Subreflector assembly **108** is movable between a first subreflector position and a second subreflector position (e.g., as illustrated by FIGS. **3-4**).

In some embodiments, support assembly **104** and/or support sub-assembly **110** includes supporting structural members, bearings, drive means, etc. for positioning and stabilizing the primary reflector **106**, sub-reflector **108**, and/or movable feed subsystem **200** (FIG. **2**). For example, the positioning and/or stabilizing elements of support assembly **104** and/or support sub-assembly **110** allow antenna system **100** to communicate with one or more satellites (e.g., while a vessel on which the antenna system **100** is located is in motion). In some aspects, the antenna support is similar to those disclosed by U.S. Pat. No. 5,419,521 entitled THREE-AXIS PEDESTAL, U.S. Pat. No. 8,542,156 entitled PEDESTAL FOR TRACKING ANTENNA, U.S. Patent Application Publication No. 2010-0295749 entitled RADOME FOR TRACKING ANTENNA, and U.S. Pat. No. 9,000,995 entitled THREE-AXIS PEDESTAL HAVING MOTION PLATFORM AND PIGGY BACK ASSEMBLIES, the entire content of which patents and publications is incorporated herein for all purposes by this reference, as well as those used in the Sea Tel® 9707, 9711 and 9797 VSAT systems, as well as other satellite communications antennas sold by Cobham SATCOM of Concord, Calif.

FIG. **2** shows a side view of antenna system **100**, in accordance with some embodiments. Antenna system **100** includes movable feed sub-system **200** that is coupled to support sub-assembly **110** of support assembly **104**. Movable feed sub-system **200** is described further with regard to FIGS. **6-8**. In some embodiments, antenna system **100** includes a stationary or fixed feed **202** that is coupled to support assembly **104**.

FIGS. **3-4** show an enlarged view of primary reflector **106** and subreflector assembly **108**, illustrating movement of subreflector assembly **108** between a first position (as shown in FIG. **3**) and a second position (as shown in FIG. **4**), in accordance with some embodiments. Movable feed sub-system **200** includes a first movable feed **304** (e.g., a K_u Feed) and a second movable feed **306** (e.g., a K_a feed) (e.g., as shown in FIG. **3**).

As discussed further with regard to FIGS. **11-13**, when subreflector assembly **108** is in a first position, as shown in FIG. **3**, a path between fixed feed **202** (e.g., a C-band feed) and primary reflector **106** is intercepted by subreflector assembly **108**. Signals traveling to and/or from first movable feed **304** and/or second movable feed **306** are deflected by subreflector assembly **108**. For example, received signals from a satellite are reflected by primary reflector **106** and by subreflector assembly **108** to arrive at first movable feed **304** and/or second movable feed **306**. Signals transmitted by first movable feed **304** and/or second movable feed **306** are reflected by subreflector assembly **108** to primary reflector **106**, which directs the transmitted signals toward a satellite.

When subreflector assembly **108** is in a second position, as shown in FIG. **4**, a path between fixed feed **202** and primary reflector **106** is not intercepted by subreflector assembly **108**. Accordingly, signals travel directly between fixed feed **202** and primary reflector **106**. Signals from first movable feed **304** and second movable feed **306** are not reflected by subreflector assembly **108** and are thus not directed to primary reflector **106**.

FIG. **5** is an enlarged view of movable feed sub-system **200**, subreflector assembly **108**, and fixed feed **202** of antenna system **100**, in accordance with some embodiments. Subreflector assembly **108** is moved between the first position shown in FIG. **3** and the second position shown in FIG. **4** by an subreflector actuator **502** (e.g., a motor). In some embodiments, subreflector actuator **502** and/or fixed feed **202** are fixedly coupled to support sub-assembly **110** of support assembly **104**. Movable feed platform **506**, to which first movable feed **304** and second movable feed **306** are mounted, is moved between a first position (e.g., as shown in FIG. **7**) and a second position (e.g., as shown in FIG. **8**) by rotatable shaft **504** that is coupled to a movable feed actuating system **600** (e.g., as shown in FIG. **6**). Because first movable feed **304** and second movable feed **306** are both fixedly mounted to a movable feed platform **506** that is moved by actuating system **600**, first movable feed **304** and second movable feed **306** are synchronously movable.

FIG. **6** shows a top perspective view of movable feed sub-system **200**, in accordance with some embodiments. Movable feed sub-system **200** includes a movable feed support bracket **602** (e.g., a component of support sub-assembly **110** of support assembly **104**) to which movable feed platform **506** is movably coupled. In some embodiments, a movable feed actuating system **600** is coupled to the movable feed support bracket **602**. Movable feed actuating system **600** includes a motor **604** that is configured to move a belt **606**. The movement of belt **606** causes rotation of a pulley **608** that is coupled to rotatable shaft **504**. The rotation of rotatable shaft **504** causes movement of movable feed platform **506** to which first movable feed **304** and second movable feed **306** are mounted. In this way, motor **604** drives rotatable shaft **504**.

It will be recognized that alternative actuating systems can be used (e.g. in lieu of the movable feed actuating system **600** illustrated in FIG. **6**) to cause movement of movable feed platform **506** and/or a counterbalance **706** (described with regard to FIG. **7**). In some embodiments, movable feed platform **506** is moved by a first solenoid (not shown). For example, the first solenoid has a base that is coupled to movable feed support bracket **602** and an actuating element that is coupled to the feed platform **506**. In some embodiments, counterbalance **706** is moved by a second solenoid (not shown) that is coupled to the counterbalance **706**. For example, the second solenoid has a base that is coupled to movable feed support bracket **602** and an actuating element that is coupled to the counterbalance **706**. In some embodiments, movable feed platform **506** is moved by a first motor (e.g., motor **604**) that is coupled to the movable feed support bracket **602**. For example, a motor is coupled directly to a rotatable shaft that is coupled to movable feed platform **506**, such that the motor causes rotation of movable feed platform **506**. In some embodiments, counterbalance **706** is moved by a second motor (not shown) that is coupled to the movable feed support bracket **602**. FIG. **14** illustrates an actuating system that includes two pulleys. FIGS. **15-29** illustrate a movable feed platform that is coupled to a first lead screw that is caused to retract and extend by a first motor and a counterbalance that is coupled to a second lead screw that is caused to retract and extend by a second motor.

FIGS. **7-8** show a bottom perspective view of movable feed sub-system **200**, illustrating movement of movable feed platform **506** from a first position (e.g., as shown in FIG. **7**) to a second position (as shown in FIG. **8**), in accordance with some embodiments. In FIG. **7**, rotatable shaft **504** is rotated to a first position, and movable feed platform **506** is at a position on the right side of feed mount track **704**.

In some embodiments, movable feed sub-system **200** includes a counterbalance **706** that is configured to move synchronously with movement of the movable feed platform **506** in a direction that is opposite of the direction of motion of the movable feed platform **506**. Counterbalance **706** is movably coupled to support bracket **602** (e.g., a component of support sub-assembly **110** of support assembly **104**). In FIG. **7**, counterbalance **706** is shown at the left end of counterbalance track **708**.

In some embodiments, counterbalance **706** includes a block upconverter (BUC). In some embodiments, the BUC is configured to convert signals generated by a signal generator to a first frequency band (e.g., the K_u-band) for transmission by the first movable feed **304**. In some embodiments, the BUC is configured to convert signals generated by the signal generator (or a different signal generator) to the second frequency band (e.g., the K_a-band) for transmission by the second movable feed **306**. In some embodiments, the BUC converts signals generated by the signal generator to a third frequency band (e.g., the C-band) and/or to additional frequency bands of the plurality of frequency bands reflected by the primary reflector **106**.

In FIG. **8**, rotatable shaft **504** is rotated to a second position, movable feed platform **506** is at a position on the left side of feed mount track **704**, and counterbalance **706** is shown at the right end of counterbalance track **708**.

FIGS. **9-10** show a bottom perspective view of movable feed support bracket **602** of movable feed sub-system **200** (shown with a partial view of movable feed platform **506** and shown with counterbalance **706** removed for illustration purposes), illustrating movement of movable feed platform **506** from a first position (e.g., as shown in FIG. **9**) to a second position (as shown in FIG. **10**), in accordance with some embodiments.

A first connector assembly, such as counterbalance arm **908**, is coupled to rotatable shaft **504** and to a counterbalance bearing **910** that slides along counterbalance track **708** (e.g., as illustrated in FIGS. **9-10**). The counterbalance bearing **910** is coupled to counterbalance bracket **904** (to which counterbalance **706**, not shown in FIG. **9**, is mounted). As rotation of rotatable shaft **504** causes movement of counterbalance arm **908**, counterbalance bearing **910**, counterbalance bracket **904**, and counterbalance **706** move along counterbalance track **708**.

A second connector assembly, such as feed mount arm **906**, is coupled to rotatable shaft **504** and to a feed mount bearing (not shown) that slides along feed mount track **704**. The feed mount bearing is coupled to movable feed platform **506**. As rotation of rotatable shaft **504** causes movement of feed mount arm **906**, the feed mount bearing and movable feed platform **506** move along feed mount track **704**. Typically, the movement of movable feed platform **506** is opposite in direction and equal in magnitude to the movement of counterbalance **706** along counterbalance track **708**.

In some embodiments, movement of movable feed platform **506** and/or counterbalance **706** (e.g., relative to movable feed support bracket **602**) is along a linear path. For example, the movable feed platform **506** moves along a linear path (e.g., along feed mount track **704**) between the first feed platform position shown in FIG. **9** and the second feed platform position shown in FIG. **10**.

In some embodiments, movement of movable feed platform **506** and/or counterbalance **706** is along a rotational path between a first feed platform position and a second feed platform position. For example, the movable feed platform **506** is directly coupled to a motor that is configured to rotate the movable feed platform **506**. In some embodiments, a second motor drives counterbalance **706** in a direction that is opposite to the motion of the movable feed platform **506**.

In some embodiments, one or more mechanical stops (e.g., pins) and/or limit switches are utilized to limit movement of movable feed platform **506** and/or counterbalance **706** (e.g., movement beyond the first position and/or the second position). For example, pins mounted to support bracket **602** restrain motion of feed platform **506** and/or counterbalance **706**.

In some embodiments, a first rubberized waveguide is coupled to the first movable feed **304** and configured to channel the first RF signal received from and/or transmitted to the first movable feed **304**. In some embodiments, a second rubberized waveguide is coupled to the second movable feed **306** and configured to channel the second RF signal received from and/or transmitted to the second movable feed **306**. The flexibility of the rubberized waveguides advantageously accommodates the motion of the movable feed platform **506**.

In FIGS. **11-12**, subreflector assembly **108** is in a first subreflector position in which the subreflector assembly **108** intersects a signal path of RF signal **1102** and RF signal **1202**. Signals travel along the signal path in a reception path direction (e.g., from a satellite to a feed) and/or in a transmission path direction (e.g., from a feed to a satellite)

FIG. **11** is a signal path diagram illustrating a signal path between a first movable feed **304** and primary reflector **106**, in accordance with some embodiments. In FIG. **11**, a movable feed platform **506** is in a first position (e.g., as illustrated in FIGS. **7** and/or **9**). Along a reception path, RF signals **1102** (e.g., **1102***a*, **1102***b*) travel from a satellite (not shown) and are reflected by primary reflector **106** to subreflector assembly **108**, which in turn reflects the RF signals **1102** to first movable feed **304**. In some embodiments, when the movable feed platform **506** is in the first movable feed platform position, the second movable feed **306** does not receive the RF signal **1102** (or any other RF signal). Along a transmission path, signals transmitted from first movable feed **304** are reflected by subreflector assembly **108** toward primary reflector **106**, which in turn reflects the RF signals **1102** to the satellite.

FIG. **12** is a signal path diagram illustrating a signal path between a second movable feed **306** and primary reflector **106**, in accordance with some embodiments. In FIG. **12**, a movable feed platform **506** is in a second position (e.g., as illustrated in FIGS. **8** and/or **10**). Along a reception path, RF signals **1202** (e.g., **1202***a*, **1202***b*) travel from a satellite (not shown) and are reflected by primary reflector **106** to subreflector assembly **108**, which in turn reflects the RF signals **1202** to second movable feed **306**. In some embodiments, when the movable feed platform **506** is in the second movable feed platform position, the first movable feed **304** does not receive the RF signal **1202** (or any other RF signal). Along a transmission path, signals transmitted from second movable feed **306** are reflected by subreflector assembly **108** toward primary reflector **106**, which in turn reflects the RF signals **1202** to the satellite.

FIGS. **11-12** are also applicable to the movement of movable feed assembly **1802** from a first position (e.g., as illustrated in FIG. **20**) to a second position (e.g., as illustrated in FIG. **21**).

In FIG. **13**, subreflector assembly **108** is in a second subreflector position in which the subreflector assembly **108** does not intersect a signal path of RF signal **1302**.

FIG. **13** is a signal path diagram illustrating a signal path between fixed feed **202** and primary reflector **106**, in accordance with some embodiments. In FIG. **13**, subreflector assembly **108** has moved from the first position shown in FIGS. **11-12** to the second position shown in FIG. **13** (e.g., as illustrated in FIGS. **3-4**). Along a reception path, RF signals **1302** (e.g., **1302***a*, **1302***b*) travel from a satellite (not shown) and are reflected by primary reflector **106** to fixed feed **202**. Along a transmission path, signals transmitted from fixed feed **202** are reflected by primary reflector **106** to the satellite.

FIG. **13** is also applicable to the movement of subreflector assembly **108** from a first subreflector position as illustrated in FIG. **16** to a second subreflector position as illustrated in FIG. **17**.

FIG. **14** illustrates an actuating system to cause movement of movable feed platform **506** and counterbalance **706**, in accordance with some embodiments. An actuator (not shown) causes movement of belt **1406**, which in turn causes rotation of a first pulley **1402** and a second pulley **1404**. (In some embodiments, one or more actuators (not shown) causes movement of first pulley **1402** and/or second pulley **1404**). Movable feed platform **506** is coupled to a first segment of belt **1406**, such that movement of belt **1406** causes movement of movable feed platform **506** in a first direction. Counterbalance **706** is coupled to a second segment of belt **1406**, such that movement of belt **1406** causes movement of counterbalance **706** in a second direction that is opposite the first direction. For example, the first segment of belt **1406** is between first pulley **1402** and second pulley **1404** on a first side of first pulley **1402** and second pulley **1404** and the second segment of belt **1406** is between first pulley **1402** and second pulley **1404** on a second side of first pulley **1402** and second pulley **1404** that is opposite the first side of first pulley **1402** and second pulley **1404**.

In some embodiments, the feed platform is moved between a first feed platform position and a second feed platform position by a first linear actuator. In some embodiments, a counterbalance is moved between a first counterbalance position and a second counterbalance position by a second linear actuator. FIGS. **15-23** illustrate a movable feed subsystem that includes a linear actuator. FIGS. **24-29** illustrate a counterbalance sub-system that includes a linear actuator for moving a counterbalance. FIGS. **30-32** illustrate a control system for controlling motion of a movable feed sub-system and a counterbalance sub-system.

FIG. **15** shows a side view of an antenna system **1500** for receiving signals having radio frequencies in a plurality of radio frequency (RF) frequency ranges, in accordance with some embodiments. Antenna system **1500** includes a movable feed sub-system **1502** that includes a first linear actuator for moving a feed platform and a counterbalance subsystem **1504** that includes a second linear actuator for moving a counterbalance. Movable feed sub-system **1502** includes a first movable feed **304** (e.g., a K_u Feed) and a second movable feed **306** (e.g., a K_a feed). Support assembly **104**, primary reflector **106**, and subreflector assembly **108** of antenna system **1500** are as described above with regard to antenna system **100**.

FIGS. **16-17** show an enlarged perspective view of primary reflector **106**, subreflector assembly **108**, and movable feed sub-system **1502**, illustrating movement of subreflector assembly **108** between a first position (as shown in FIG. **16**) and a second position (as shown in FIG. **17**), in accordance with some embodiments. As discussed further with regard to FIGS. **11-13**, when subreflector assembly **108** is in a first position, as shown in FIG. **16**, a path between fixed feed **202** (e.g., a C-band feed) and primary reflector **106** is intercepted by subreflector assembly **108**. Accordingly, in FIG. **16**, signals traveling to and/or from first movable feed **304** and/or second movable feed **306** are deflected by subreflector assembly **108**. When subreflector assembly **108** is in a second position, as shown in FIG. **17**, a path between fixed feed **202** and primary reflector **106** is not intercepted by subreflector assembly **108**. Accordingly, signals travel directly between fixed feed **202** and primary reflector **106**. In FIG. **17**, signals from first movable feed **304** and second movable feed **306** are not reflected by subreflector assembly **108** and are thus not directed to primary reflector **106**.

FIGS. **18-19** are enlarged front perspective views of movable feed sub-system **1502** that includes a linear actuator, in accordance with some embodiments. As shown in FIG. **18**, first movable feed **304** and second movable feed **306** are mounted to a movable feed assembly **1802** that is moved along one or more tracks (e.g., a first track **1804**, a second track **1806**, a third track **2202**, and/or a fourth track **2208**) between a first position (e.g., as shown in FIG. **20**) and a second position (e.g., as shown in FIG. **21**). In FIG. **19**, a linear actuator system **1902** is shown. Linear actuator system **1902** includes a motor **1904**. In some embodiments, linear actuator system **1902** includes a linkage that translates the turning motion imparted by the motor **1904** into linear motion of the movable feed assembly **1802** along one or more tracks. For example, linear actuator system **1900** includes a lead screw **1906** that translates the turning motion of the motor **1904** into linear motion of movable feed assembly **1802**. In some embodiments, lead screw **1906** is rotated by motor **1904** via an internal gear (not shown).

FIGS. **20-21** are enlarged front perspective views of movable feed sub-system **1502** that illustrate movement of movable feed assembly **1802** between a first position and a second position, in accordance with some embodiments. In some embodiments, movable feed assembly **1802** is coupled to lead screw **1906** via a connector as indicated at **2002**. Movable feed assembly **1802** is movably coupled to track **1806** via bearings **2004** and **2008**, to track **1804** via a bearing **2006**, to track **2202** via bearings **2204** and **2206** (see FIG. **22**), and to track **2208** via bearing **2210** (see FIG. **22**). Bearings **2004**, **2006**, **2204**, **2206**, and/or **2208** stabilize movable feed assembly **1802** relative to a support structure of movable feed sub-system **1502** (e.g., by restricting motion of movable feed assembly **1802** to an axis that is parallel to the axis along which lead screw **1906** extends and retracts).

In FIG. **20**, lead screw **1906** is shown in an extended position (e.g., such that first movable feed **304** is aligned along a signal path with subreflector **108** for transmission of signals between primary reflector **106** and first movable feed **304**). From FIG. **20** to FIG. **21**, motor **1904** has caused retraction of lead screw **1906** (e.g., such that second movable feed **306** is aligned along a signal path with subreflector **108** for transmission of signals between primary reflector **106** and second movable feed **306**). As lead screw **1906** retracts, movable feed assembly **1802** is moved (e.g., via connector **2002**) such that bearing **2004** moves along track **1806** and bearing **2006** moves along track **1804**.

FIG. **22** illustrates an enlarged rear perspective view of movable feed sub-system **1502**, in accordance with some embodiments. Bearings **2204** and **2206** are coupled to movable feed assembly **1802** and are configured to move along track **2202**. Bearing **2210** is coupled to movable feed assembly **1802** and is configured to move along track **2208**. In some embodiments, movable feed sub-system **1502** includes one or more handles (e.g., handle **2212** and handle **2214**) to aid in installation of movable feed sub-system **1502** to antenna system **1500**.

FIG. **23** illustrates an enlarged rear elevation view of movable feed sub-system **1502**, in accordance with some embodiments. In some embodiments, movable feed subsystem **1502** includes limit switches **2302** and **2304**. When bearing **2206** comes into contact with an actuator of limit switch **2302** (e.g., as linear actuator system **1902** causes movement of movable feed assembly **1802** from a first position (e.g., as shown in FIG. **20**) to a second position (e.g., as shown in FIG. **21**)), switching occurs (e.g., an electrical connection is made between a set of contacts of limit switch **2302**). When bearing **2206** comes into contact with an actuator of limit switch **2304** (e.g., as linear actuator system **1902** causes movement of movable feed assembly **1802** from the second position to the first position), switching occurs (e.g., an electrical connection is made between a set of contacts of limit switch **2304**). In some embodiments, movable feed sub-system **1502** includes stop blocks **2306** and **2308**. Stop block **2306** is a mechanical stop that limits motion of movable feed assembly **1802** beyond a fixed point as linear actuator system **1902** causes movement of movable feed assembly **1802** from a first position to a second position. Stop block **2308** is a mechanical stop that limits motion of movable feed assembly **1802** beyond a fixed point as linear actuator system **1902** causes movement of movable feed assembly **1802** from the second position to the first position.

In some embodiments, limit switches **2302** and **2304** are used to detect whether movable feed assembly **1802** reached the first position and the second position, respectively. In some embodiments, limit switch **2302** is coupled to movable feed sub-system **1502** at a fixed linear distance (e.g., ⅜") from stop block **2306** along track **2202**. In this way, as movable feed assembly **1802** passes limit switch **2302** but before movable feed assembly **1802** reaches stop block **2306**, the motion of the motor **1904** is decelerated in response to the switching of limit switch **2302** (e.g., such that motor **1904** does not operate at full speed as movable feed assembly **1802** reaches stop block **2306**, which could result in overheating of and/or damage to the motor). In some embodiments, limit switch **2304** is coupled to movable feed sub-system **1502** at a fixed linear distance (e.g., ⅜") from stop block **2308** along track **2202**, such that as movable feed assembly **1802** passes limit switch **2304**, but before movable feed assembly **1802** reaches stop block **2308**, the motion of the motor **1904** is decelerated in response to the switching of limit switch **2304** (e.g., such that motor **1904** does not operate at full speed as movable feed assembly **1802** reaches stop block **2308**.

FIGS. **24-25** illustrate movement of movable feed assembly **1802** of movable feed sub-system **1502** and corresponding movement of counterbalance **2402** of counterbalance sub-system **1504** as movable feed assembly **1802** moves between a first position and a second position, in accordance with some embodiments. In some embodiments, counterbalance **2402** is configured to move synchronously with movement of the movable feed assembly **1802** in a direction that is opposite of the direction of motion of the movable feed assembly **1802**. For example, as movable feed assembly **1802** moves in a first direction along elevation axis **2606** (see FIG. **26**) from a first position shown in FIG. **24** to a second position shown in FIG. **25** (e.g., via retraction of lead screw **1906**), counterbalance **2402** moves in an opposite direction along elevation axis **2606**.

FIG. **26** shows a perspective view of movable feed sub-system **1502** and counterbalance **2402** of counterbalance sub-system **1504** relative to a coordinate system defined by an azimuth axis **2602**, a cross level axis **2604**, and an elevation axis **2606**, in accordance with some embodiments.

FIG. **27** is an enlarged view of counterbalance sub-system **1504**, in accordance with some embodiments. Counterbalance sub-system **1504** includes a linear actuator system **2702**. Linear actuator system **2702** includes a motor **2704**. In some embodiments, linear actuator system **2702** includes a linkage that translates the turning motion imparted by the motor **2702** into linear motion of the counterbalance along one or more tracks (e.g., track **2802**). For example, linear actuator system **2702** includes a lead screw **2706** that translates the turning motion of the motor **2704** into linear motion of counterbalance **2402**. In some embodiments, lead screw **2706** is coupled to motor **2704** via an internal gear (not shown).

FIG. **28** illustrates an enlarged view of linear actuator system **2702** for movement of counterbalance **2402**, in accordance with some embodiments. Bearing **2804** is coupled to counterbalance **2402** and is configured to move along track **2802**. In some embodiments, counterbalance sub-system **1504** includes limit switches **2806** and **2808**. When bearing **2804** comes into contact with an actuator of limit switch **2808** (e.g., as linear actuator system **2702** causes movement of counterbalance **2402** from a first position (e.g., as shown in FIG. **28**) to a second position (e.g., as shown in FIG. **29**)), switching occurs (e.g., an electrical connection is made between a set of contacts of limit switch **2808**). When bearing **2804** comes into contact with an actuator of limit switch **2806** (e.g., as linear actuator system **2702** causes movement of counterbalance **2402** from the second position to the first position), switching occurs (e.g., an electrical connection is made between a set of contacts of limit switch **2806**). In some embodiments, limit switches **2806** and **2808** are used to detect whether counterbalance **2402** has reached the first position and the second position, respectively. In some embodiments, limit switches **2806** and **2808** are used to decelerate the motor as counterbalance **2402** approaches the first position and the second position, respectively.

From FIG. **28** to FIG. **29**, motor **2704** has caused extension of lead screw **2706**. As lead screw **2706** extends, counterbalance **2402** is moved such that bearing **2804** moves along track **2802**.

FIG. **30** is a system diagram of an antenna control unit, in accordance with some embodiments. In some embodiments, antenna control unit **3002** includes one or more processors for processing communication signals and/or providing instructions for moving one or more elements of antenna system **1500**. Antenna control unit **3002** is communicatively coupled to a feed actuating system motor interface board **3004** and counterbalance motor interface board **3012**.

Feed actuating system motor interface board **3004** is communicatively coupled to motor **1904**. For example, actuating system motor interface board **3004** generates an instruction for operating motor **1904** in order to adjust a position of movable feed assembly **1802**. In some embodiments, feed actuating system motor interface board **3004** is coupled to outer limit switch **2304** and inner limit switch **2302**. For example, counterbalance motor interface board **3012** receives switching signals from limit switch **2302** and/or **2304**. In some embodiments, a signal from a limit switch is used to determine whether the movable feed assembly **1802** reached a position that corresponds to a respective limit switch **2302** or **2304**. In some embodiments, a signal from a limit switch is used to decelerate motion of the motor as the movable feed assembly **1802** moves toward the first position or the second position.

Counterbalance motor interface board **3012** is communicatively coupled to motor **2704**. For example, counterbalance motor interface board **3012** generates an instruction for operation of motor **2704** in order to adjust a position of counterbalance **2402**. In some embodiments, counterbalance motor interface board **3012** is coupled to outer limit switch **2808** and inner limit switch **2806**. For example, counterbalance motor interface board **3012** receives signals from limit switch **2808** and/or **2806**. In some embodiments, a signal from a limit switch is used to determine whether the counterbalance **2402** reached a position that corresponds to a respective limit switch **2806** or **2808**. In some embodiments, a signal from a limit switch is used to decelerate motion of the motor **2704** as the counterbalance **2402** moves toward the first position or the second position.

FIG. **31** illustrates parallel operation of motor **1904** and motor **2704**, in accordance with some embodiments. In some embodiments, in accordance with a determination that band-switching is to be performed (e.g., from a Ku-band to a Ka-band or vice versa), antenna control unit **3002** transmits, in parallel, an instruction to feed actuation system motor interface board **3004** for activating motor **1904**, as illustrated by arrow **3102**, and an instruction to counterbalance motor interface board **3012** for activating motor **2704**, as illustrated by arrow **3104**. Feed actuation system motor interface board **3004** transmits an instruction, as illustrated by arrow **3106**, to motor **1904** for moving movable feed assembly **1802**. Counterbalance motor interface board **3012** transmits an instruction, as illustrated by arrow **3108**, to motor **2704** for moving counterbalance **2402**.

In some embodiments, in accordance with a determination (e.g., after an instruction **3102** was transmitted for moving movable feed assembly **1802**) that bearing **2206** did not reach a position that corresponds to a respective limit switch **2304** or **2302** (e.g., indicating a motor failure), antenna control unit **3002** transmits an instruction to stop and/or reverse motion of counterbalance **2402** (e.g., to maintain balance of the movable feed assembly **1802** and the counterbalance **2402**). In some embodiments, in accordance with a determination (e.g., after an instruction **3104** was transmitted for moving counterbalance **2402**) that bearing **2804** did not reach a position that corresponds to a respective limit switch **2806** or **2808** (e.g., indicating a motor failure), antenna control unit **3002** transmits an instruction to stop and/or reverse motion of movable feed assembly **1802** (e.g., to maintain balance of the movable feed assembly **1802** and the counterbalance **2402**).

FIGS. **32**A-**32**D are system diagrams that illustrate serial operation of motor **1904** and motor **2704**, in accordance with some embodiments. Operation of a motor **1904** that is serially connected to motor **2704** beneficially causes motion of one motor to stop when the other motor is non-operational, thereby maintaining a counterbalance between components of movable feed assembly **1802** and counterbalance **2402**.

FIGS. **32A-32C** illustrate a first approach to serial operation of motor **1904** and motor **2704**. In FIG. **32**A, in accordance with a determination that band-switching is to be performed (e.g., from a Ku-band to a Ka-band or vice versa), antenna control unit **3002** transmits a motor operation instruction to feed actuation system motor interface board **3004**, as illustrated by arrow **3202**. In FIG. **32**B, feed actuator interface board **3004** transmits the motor operation instruction to counterbalance actuator interface board **3012** via antenna control unit **3002**, as illustrated by arrows **3204-3206**. In FIG. **32**C, feed actuation system motor interface board **3004** transmits an instruction to motor **1904** for moving movable feed assembly **1802**, as illustrated by arrow **3208**, and counterbalance motor interface board **3012** transmits an instruction to motor **2704** for moving counterbalance **2402**, as illustrated by arrow **3210**. In this way, if a failure in feed actuating system motor interface board **3004** prevents control of motor **1904**, counterbalance motor interface board **3012** is also prevented from controlling motor **2704** such that a balance between movable feed assembly **1802** and counterbalance **2402** is maintained.

FIG. **32**D illustrates a second approach to serial operation of motor **1904** and motor **2704**. In FIG. **32**D, in accordance with a determination that band-switching is to be performed (e.g., from a Ku-band to a Ka-band or vice versa), antenna control unit **3002** transmits a motor operation instruction to feed actuating system motor interface board **3004**, as illustrated by arrow **3250**. Feed actuator interface board **3004** transmits the motor operation instruction to motor **1904**, as illustrated by arrow **3252**. A signal is transmitted from motor **1904** (as shown), outer limit switch **2304**, and/or inner limit switch **2302** to motor **2704**, as illustrated by arrow **3254**. In this way, a condition (e.g., failure) of motor **1904** that prevents or otherwise affects operation of motor **1904** causes, via the serial connection (e.g., between the motor **1904** and motor **2704**), operation of motor **2704** to be altered. In this way, balance between movable feed assembly **1802** and counterbalance **2402** is maintained. A signal, as indicated by arrow **3256**, is transmitted from motor **2704** (as shown), outer limit switch **2808**, and/or inner limit switch **2806** to counterbalance motor interface board **3012** (e.g., to indicates a state of operation of motor **2704**). Counterbalance motor interface board **3012** transmits a signal to antenna control unit **3002**, as indicated by arrow **3258** (e.g., to indicates a state of operation of motor **2704**). In some embodiments, antenna control unit **3002** determines a motor operation instruction to transmit to feed actuating system motor interface board **3004** using the signal indicated by arrow **3258**. In this way, a condition (e.g., failure) of motor **2704** that prevents or otherwise affects operation of motor **2704** causes, via the serial connection (e.g., between the motor **2704** and motor **1904** along a path indicated by arrows **3256**, **3258**, **3250**, and **3252**), operation of motor **1904** to be altered. It will be recognized that, in accordance with various embodiments, the signal transmission path described above with regard to arrows **3250-3258** is reversed.

FIGS. **33**A-**33**B are flow diagrams illustrating a method **3300** for receiving signals having frequencies in a plurality of radio frequency (RF) frequency ranges, in accordance with some embodiments. The method **3300** is performed at a device, such as an antenna system (e.g., antenna system **100** or antenna system **1500**) that includes: a support assembly **104**, a primary reflector **106** that is coupled to the support assembly **104**, a feed assembly (e.g., movable feed platform **506** or movable feed assembly **1502**) that is movably coupled to the support assembly **104**, a first actuator (e.g., **604** or **1904**) configured to move the movable feed assembly, a first movable feed **304** fixedly coupled to the movable feed assembly, and a second movable feed **306** fixedly coupled to the movable feed assembly. The primary reflector **106** receives and reflects RF signals in a plurality of frequency bands (e.g., the C-band, the K_a-band, and the K_u-band). In some embodiments, the feed assembly is coupled to the primary reflector **106** (e.g., in lieu of being coupled to the support assembly or in addition to being coupled to the support assembly). In some embodiments, the antenna system includes a computing system with one or more processors and memory. For example, instructions for performing the method **3300** are stored in the memory and executed by the one or more processors. In some embodiments, part or all of the instructions for performing the method **3300** are performed by antenna control unit **3002**.

The first actuator moves (**3302**) the movable feed assembly (e.g., movable feed platform **506** or movable feed assembly **1802**) between a first feed platform position (e.g., as illustrated in FIG. **7** or as illustrated in FIG. **20**) and a second feed platform position (e.g., as illustrated in FIG. **8** or as illustrated in FIG. **21**). For example, an actuator system **600** including a motor **604**, as described with regard to FIG. **6**, moves the movable feed platform **506**. In some embodiments, the feed assembly moves (**3304**) along a linear path between the first feed assembly position and the second feed assembly position. For example, a linear actuator system **1902** including a motor **1904**, as described with regard to

FIG. **19**, moves the movable feed assembly **1802** along one or more tracks (e.g., tracks **1804**, **1806**, **2202**, and/or **2208**) via extension and retraction of a lead screw **1906**. In some embodiments, the feed assembly moves (**3306**) along a rotational path between the first feed assembly position and the second feed assembly position.

When the feed assembly is in the first feed assembly position, the antenna system **100** receives (**3308**), by the first movable feed **304**, a first RF signal in a first frequency band (e.g., the K_u-band) of the plurality of frequency bands reflected from the primary reflector **106**.

When the feed assembly is in the second feed assembly position, the antenna system **100** receives (**3310**), by the second movable feed **306**, a second signal in a second frequency band (e.g., the K_a-band) of the plurality of frequency bands reflected from the primary reflector.

In some embodiments, a second actuator moves (**3312**) a subreflector assembly **108** from a first subreflector position to a second subreflector position (e.g., as shown in FIGS. **3-4**, FIGS. **12-13**, and/or FIGS. **16-17**). When the subreflector assembly **108** is in the first subreflector position and the movable feed assembly **506** is in the first feed assembly position (e.g., as shown in FIG. **11**), the subreflector assembly **108** reflects the first RF signal received from the primary reflector **106** to the first movable feed **304**. When the subreflector assembly **108** is in the first subreflector position and the feed assembly is in the second feed assembly position (e.g., as shown in FIG. **12**), the subreflector assembly reflects the second RF signal received from the primary reflector **106** to the second movable feed **306**. When the subreflector assembly is in the second subreflector position (e.g., as shown in FIG. **13**), a third feed **202** receives a third RF signal in a third frequency band (e.g., the C-band), directly from the primary reflector **106**.

In some embodiments, antenna system **100** transmits signals in one or more frequency bands. In some embodiments (**3314**), when the subreflector assembly **108** is in the first subreflector position and the movable feed assembly is in the first feed assembly position (e.g., as shown in FIG. **11**), the subreflector assembly **108** reflects a fourth RF signal in the first frequency band (e.g., the K_u-band) transmitted from the first movable feed **304** to the primary reflector **106**. When the subreflector assembly **108** is in the first subreflector position and the feed assembly is in the second feed assembly position (e.g., as shown in FIG. **12**), the subreflector assembly **108** reflects a fifth RF signal in the second frequency band (e.g., the K_a-band) transmitted from the second movable feed **306** to the primary reflector **106**. When the subreflector assembly is in the second subreflector position (e.g., as shown in FIG. **13**), the third feed **202** transmits a sixth RF signal in the third frequency band (e.g., the C-band) directly to the primary reflector **106**.

In some embodiments, antenna system **100** moves (**3316**) a counterbalance (e.g., counterbalance **706** that is movably coupled to movable feed sub-system **200** or counterbalance **2402** that is movably coupled to support assembly **104**). The counterbalance is configured to move synchronously with movement of the movable feed assembly in a direction that is opposite to the direction of motion of the movable feed assembly. Movement of a counterbalance (e.g., **706** or **2402**) in a direction that is opposite to the movement of the movable feed platform (e.g., **506** or **1802**) avoids undesired movement of components of antenna **100** due to motion of the movable feed platform for band switching.

In some embodiments, the counterbalance (e.g., counterbalance **706** or counterbalance **2402**) includes a plurality (e.g., 2-5) of weight components (e.g., metal weights, such as steel plates). In some embodiments, one or more of the weight components of the counterbalance is removable (e.g., such that the total amount of weight of the counterbalance is adjustable). In some embodiments, the counterbalance includes a support device (e.g., a bracket) for supporting an additional weight component.

In some embodiments, the counterbalance (e.g., counterbalance **706**) includes a block upconverter that converts (**3318**) signals generated by a signal generator to the first frequency band (e.g., the K_u-band) for transmission by the first movable feed **304** and converts signals generated by the signal generator to the second frequency band (e.g., the K_a-band) for transmission by the second movable feed **306**.

In some embodiments, the feed assembly and the counterbalance are coupled to the movable feed sub-system. For example, as shown in FIG. **7**, movable feed platform **506** and counterbalance **706** are movably coupled to movable feed sub-system **200**. In some embodiments, primary reflector **106** is positioned between the feed assembly and the counterbalance. For example, as shown in FIGS. **15** and **24**, movable feed sub-system **1502** is coupled to support assembly **104** and/or primary reflector **106** (e.g., such that reflecting surface of primary reflector **106** faces movable feed assembly **1802**) and counterbalance sub-system **1504** is coupled to support assembly **104** (e.g., such that the non-reflecting surface of primary reflector **106** faces counterbalance **2402**). Locating the counterbalance remotely from the feed assembly (e.g., by positioning the counterbalance and the feed assembly on opposite sides of primary reflector **106**) advantageously distributes the added weight of the feed assembly and the counterbalance. For a feed assembly that is at least partially supported by support structure(s) coupled to primary reflector **106**, locating the counterbalance remotely from the feed assembly reduces deflection of the primary reflector **106**.

Features of the present invention can be implemented in, using, or with the assistance of a computer program product, such as a storage medium (media) or computer readable storage medium (media) having instructions stored thereon/in which can be used to program a processing system to perform any of the features presented herein. The storage medium can include, but is not limited to, high-speed random access memory, such as DRAM, SRAM, DDR RAM or other random access solid state memory devices, and may include non-volatile memory, such as one or more magnetic disk storage devices, optical disk storage devices, flash memory devices, or other non-volatile solid state storage devices. Memory optionally includes one or more storage devices remotely located from the CPU(s). Memory or alternatively the non-volatile memory device(s) within memory comprises a non-transitory computer readable storage medium.

Stored on any one of the machine readable medium (media), features of the present invention can be incorporated in software and/or firmware for controlling the hardware of a processing system, and for enabling a processing system to interact with other mechanism utilizing the results of the present invention. Such software or firmware may include, but is not limited to, application code, device drivers, operating systems, and execution environments/containers.

It will be understood that, although the terms “first,” “second,” etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the claims. As used in the description of the embodiments and the appended claims, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will also be understood that the term "and/or" as used herein refers to and encompasses any and all possible combinations of one or more of the associated listed items. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

As used herein, the term "if" may be construed to mean "when" or "upon" or "in response to determining" or "in accordance with a determination" or "in response to detecting," that a stated condition precedent is true, depending on the context. Similarly, the phrase "if it is determined [that a stated condition precedent is true]" or "if [a stated condition precedent is true]" or "when [a stated condition precedent is true]" may be construed to mean "upon determining" or "in response to determining" or "in accordance with a determination" or "upon detecting" or "in response to detecting" that the stated condition precedent is true, depending on the context.

The foregoing description, for purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the claims to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain principles of operation and practical applications, to thereby enable others skilled in the art.

What is claimed is:

1. An antenna system for communicating signals having radio frequencies in a plurality of radio frequency (RF) bands, the antenna system comprising:

a support assembly;

a primary reflector that is coupled to the support assembly, wherein the primary reflector is configured to receive and reflect RF signals in the plurality of RF frequency bands;

a feed assembly that is movably coupled to the support assembly;

a first feed fixedly coupled to the feed assembly, where the first feed is configured to communicate RF signals in a first frequency band of the plurality of RF frequency bands;

a second feed fixedly coupled to the feed assembly, where the second feed is configured to communicate RF signals in a second frequency band of the plurality of RF frequency bands; and

a first actuator coupled to the feed assembly and configured to move the feed assembly that includes both the first feed and the second feed, from a first feed assembly position, where the first feed is positioned along a first signal path with the primary reflector, to a second feed assembly position, different from the first feed assembly position, where the second feed is positioned along a second signal path with the primary reflector, and the first feed and the second feed are positioned at positions around an outer perimeter of the primary reflector and offset from a center portion of the primary reflector.

2. The antenna system of claim **1**, including:

a third feed fixedly coupled to the support assembly, where the third feed is configured to communicate RF signals in a third frequency band of the plurality of RF frequency bands; and

a subreflector assembly movably coupled to the support assembly, wherein the subreflector is movable, by a second actuator, between a first subreflector position and a second subreflector position, and wherein the antenna system is configured such that:

when the subreflector assembly is in the first subreflector position and the feed assembly is in the first feed assembly position, the subreflector assembly is positioned along the first signal path to reflect RF signals in the first frequency band between the primary reflector and the first feed;

when the subreflector assembly is in the first subreflector position and the feed assembly is in the second feed assembly position, the subreflector assembly is positioned along the second signal path to reflect RF signals in the second frequency band between the primary reflector and the second feed; and

when the subreflector assembly is in the second subreflector position, the third feed is positioned to receive RF signals in the third frequency band of the plurality of RF frequency bands directly from the primary reflector.

3. The antenna system of claim **2**, wherein when the subreflector assembly is in the first subreflector position, the subreflector assembly intersects at least one of the first signal path or the second signal path.

4. The antenna system of claim **1**, wherein the antenna system is configured such that:

when the feed assembly is in the first feed assembly position, the second feed is not positioned to communicate RF signals in the second frequency band; and

when the feed assembly is in the second feed assembly position, the first feed is not positioned to communicate RF signals in the first frequency band.

5. The antenna system of claim **1**, wherein:

the first actuator includes a first motor that is configured to drive a first lead screw; and

the first lead screw is coupled to the feed assembly, such that the driving of the first lead screw causes movement of the feed assembly.

6. The antenna system of claim **1**, including a counterbalance that is movably coupled to the support assembly, wherein the counterbalance is configured to dynamically balance movement of the feed assembly via movement in a direction that is opposite to a direction of motion of the feed assembly.

7. The antenna system of claim **6**, wherein the counterbalance includes a plurality of weight components.

8. The antenna system of claim **6**, wherein the counterbalance includes a block upconverter configured to:

convert signals generated by a signal generator to signals having frequencies in the first frequency band for transmission by the first feed, and

convert signals generated by the signal generator to signals having frequencies in the second frequency band for transmission by the second feed.

9. The antenna system of claim **6**, wherein:

the first actuator is a first motor that is configured to drive a rotatable shaft; and

the antenna system includes a second motor that is configured to drive the counterbalance.

10. The antenna system of claim 6, wherein:

the first actuator is a motor that is configured to drive a rotatable shaft;

the rotatable shaft is coupled to a first connector assembly configured to drive the feed assembly; and

the rotatable shaft is coupled to a second connector assembly configured to drive the counterbalance.

11. The antenna system of claim 6, wherein:

a third actuator includes a second motor that is configured to drive a second lead screw; and

the second lead screw is coupled to the counterbalance, such that the driving of the second lead screw causes movement of the counterbalance.

12. The antenna system of claim 6, wherein:

the first actuator is a first solenoid that is coupled to the feed assembly; and

the antenna system includes a second solenoid that is coupled to the counterbalance.

13. The antenna system of claim 6, wherein the primary reflector is positioned between the feed assembly and the counterbalance.

14. The antenna system of claim 1, including:

a first rubberized waveguide coupled to the first feed and configured to receive a first RF signal in the first frequency band from the first feed; and

a second rubberized waveguide coupled to the second feed and configured to receive a second RF signal in the second frequency band from the second feed.

15. The antenna system of claim 1, wherein the feed assembly moves along a linear path between the first feed assembly position and the second feed assembly position.

16. The antenna system of claim 1, wherein the feed assembly moves along a rotational path between the first feed assembly position and the second feed assembly position.

17. A method for receiving signals having frequencies in a plurality of radio frequency (RF) bands, the method comprising:

at an antenna system that includes:

a support assembly;

a primary reflector that is coupled to the support assembly, wherein the primary reflector is configured to receive and reflect RF signals in the plurality of RF frequency bands;

a feed assembly that is movably coupled to the support assembly;

a first actuator configured to move the feed assembly;

a first feed fixedly coupled to the feed assembly; and

a second feed fixedly coupled to the feed assembly;

moving, by the first actuator coupled to the feed assembly, the feed assembly that includes both the first feed and the second feed, between a first feed assembly position and a second feed assembly position different from the first feed assembly position;

when the feed assembly is in the first feed assembly position, receiving, by the first feed, a first RF signal in a first frequency band of the plurality of RF frequency bands reflected from the primary reflector; and

when the feed assembly is in the second feed assembly position, receiving, by the second feed, a second RF signal in a second frequency band of the plurality of RF frequency bands reflected from the primary reflector, and the first feed and the second feed are positioned at positions around an outer perimeter of the primary reflector and offset from a center portion of the primary reflector.

18. The method of claim 17, including moving, by a second actuator, a subreflector assembly from a first subreflector position to a second subreflector position, wherein:

when the subreflector assembly is in the first subreflector position and the feed assembly is in the first feed assembly position, the subreflector assembly reflects the first RF signal received from the primary reflector to the first feed;

when the subreflector assembly is in the first subreflector position and the feed assembly is in the second feed assembly position, the subreflector assembly reflects the second RF signal received from the primary reflector to the second feed; and

when the subreflector assembly is in the second subreflector position, a third feed receives a third RF signal in a third frequency band, directly from the primary reflector.

19. The method of claim 18, wherein when the subreflector assembly is in the first subreflector position and the feed assembly is in the first feed assembly position, the subreflector assembly reflects a fourth RF signal in the first frequency band transmitted from the first feed to the primary reflector;

when the subreflector assembly is in the first subreflector position and the feed assembly is in the second feed assembly position, the subreflector assembly reflects a fifth RF signal in the second frequency band transmitted from the second feed to the primary reflector; and

when the subreflector assembly is in the second subreflector position, the third feed transmits a sixth RF signal in the third frequency band directly to the primary reflector.

20. The method of claim 17, including moving a counterbalance that is movably coupled to the support assembly, wherein the counterbalance is configured to dynamically balance movement of the feed assembly via movement in a direction that is opposite to a direction of motion of the feed assembly.

21. The method of claim 20, including:

converting, by a block upconverter included in the counterbalance, signals generated by a signal generator to the first frequency band for transmission by the first feed, and converting, by the block upconverter, signals generated by the signal generator to the second frequency band for transmission by the second feed.

22. The method of claim 17, including moving the feed assembly along a linear path between the first feed assembly position and the second feed assembly position.

23. The method of claim 17, including moving the feed assembly along a rotational path between the first feed assembly position and the second feed assembly position.

24. An antenna system for receiving signals having frequencies in a plurality of radio frequency (RF) frequency bands, the antenna system comprising:

support means for supporting a primary reflector, wherein the primary reflector receives and reflects RF signals in a plurality of RF frequency bands;

a feed assembly that is movably coupled to the support means;

a first signal receiving means fixedly coupled to the feed assembly;

a second signal receiving means fixedly coupled to the feed assembly; and

means for moving the feed assembly that includes both the first signal receiving means and the second signal receiving means, from a first feed assembly position, where the first signal receiving means is positioned to receive a first RF signal in a first frequency band of the plurality of RF frequency bands from the primary reflector, to a second feed assembly position, where the second signal receiving means is positioned to receive a second RF signal in a second frequency band of the plurality of RF frequency bands from the primary reflector, and wherein the means for moving the feed assembly is coupled to the feed assembly, and first signal receiving means and the second signal receiving means are positioned at positions around an outer perimeter of the primary reflector and offset from a center portion of the primary reflector.

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